CHEMICAL & METALLURGICAL ENGINEERING

CHEMICAL EXPOSITION AND BUYERS' GUIDE ISSUE

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THE FOUNDATION OF INDUSTRY

Each year, science, replacing rule-of-thumb, advances American industry. To chemists and chemical engineering this development presents both an inspiration and an opportunity. Chemical control of industry, proved by test of war emergency during the last four years, is no longer a dream but a reality; and, marking another milestone of progress, Chemical and Metallurgical Engineering in this issue reaffirms its faith in these tenets:

Education in the fundamentals of science and mathematics, with intelligent perception of their industrial applications.

Research into the physical and chemical properties of the elements and their combinations.

Substitution of scientific principles for rule-of-thumb practice in industrial processes.

Coördination of education, research and industry for the safety and independence of the nation.

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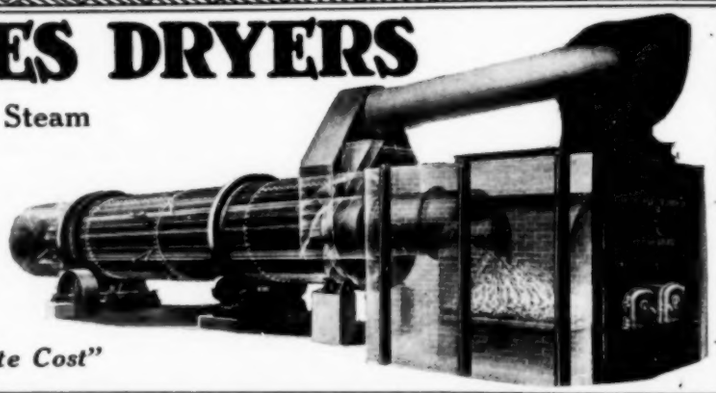

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CHEMICAL & METALLURGICAL ENGINEERING

A consolidation of
ELECTROCHEMICAL & METALLURGICAL INDUSTRY *and* IRON & STEEL MAGAZINE

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Volume 23 — New York, September 8, 1920 — *Number* 10

Putting Our Industries On a Scientific Basis

IT IS neither possible nor advisable to characterize each issue of a technical magazine by a special selection or arrangement of its editorial contents. But occasionally there is advantage in selecting a broad theme and building around it as complete a structure as possible. Accordingly in this issue of CHEMICAL & METALLURGICAL ENGINEERING we have adopted an editorial plan to which all else is subordinated.

We have always preached the doctrine of applying scientific methods to industrial processes, believing that therein lies our hope of industrial independence and supremacy. This was brought home in the most forcible manner during the war, and since then the rapid adoption of science by industry has been one of the most hopeful elements in our industrial development. And yet much remains to be done to put our industries on a scientific basis. It was with this in mind that we conceived the idea of inviting forward-looking leaders in a group of industries to forecast the scientific developments and applications which must be made if industry is to prosper and flourish in the highest degree. The hearty response to our invitation indicated the extent to which men in all branches of industry are thinking along this line. Some of the contributors to this issue have been delightfully frank, acknowledging the shortcomings of their respective industries and pointing the way to the researches and developments that should be made. In fact we were deprived of the privilege of publishing one article because its author showed a state of affairs so distasteful and uncomplimentary to his principals that they requested him to withdraw the article.

Sugar production is one of our principal industries and in his article on this subject Mr. DAHLBERG shows the possibility of building a byproduct chemical industry on factory refuse. This line of investigation is now engaging the attention of one of our largest beet-sugar companies. The problems of the petroleum industry as forecast by Mr. HAMOR consist principally in a better utilization of present supplies by varying the products of distillation to meet the changing demand. "Cracking," or pyrolysis as Mr. HAMOR more aptly calls it, is still a fertile field for investigation. Dr. WASHBURN shows us clearly in his article that the progress of technology is dependent on the interpretation and application of existing physicochemical knowledge; and this is supplemented by Dr. RICHARDS in his plea for "more and better tools" with which to work. The influence which science is bringing to bear on the treatment of sewage and trade waste is removing much of the obnoxious element in past processes and making possible the handling of these materials without offense. Mr. BAILEY writes instructively of the vegetable-oil industry, which is assuming such vast proportions. Future problems are concerned with the production of crude oils and fats, their refining and the finished products. Research is indicated in methods of solvent-extraction instead of pressing. In the rubber industry we are informed that better physical tests are needed for the guidance of manufacturers, and it appears that future developments will be along physical rather than chemical lines. Mr. STEVENS shows that the great problem of the pulp and paper industry is fuel conservation, the improved design of mechanical equipment and the adoption of vacuum driers. Dr. BANCROFT writes entertainingly on his favorite subject of applied colloid chemistry and illustrates its relation to some practical problems.

The leather industry, according to Mr. WILSON, is greatly in need of fundamental theoretical knowledge, and he feels that the greatest good can be accomplished for his industry through co-operation between university and tannery chemists, the former bringing their fundamental knowledge to bear on the practical work of the latter. The glass industry, we are informed by Dr. TILLOTSON, is indebted for its present position and prospective progress to the application of mechanical engineering in the use of automatic machinery. In the hardwood distillation industry there is much the same need as is evidenced in the petroleum industry for ability to control the nature of the products in accordance with the industrial demand for them. Mr. HAWLEY also discusses the prospect of altering the products of distillation by introducing chemicals into the kiln with the wood. In the paint and varnish industry Mr. TOCH points out the necessity of studying possibilities of blending materials which themselves may be inferior but which in combination may produce a superior product. New pigments also form an attractive field for research. In his article on alloys Dr. FINK reveals an almost unlimited field for research in the production of unusual alloys to meet the ever growing demands of special service. Mr. TUNISON has traced the influence of science on the manufacture of industrial alcohol, illustrating the progress in still and rectifier design. A large field for research remains in the development of byproducts. The future of the animal products industry, according to Mr. RICHARDSON, will be centered primarily in byproducts—the aim of the industry being to convert as much as possible of the material into food. The byproducts range from glue to enzymes. Artificial leather and coated fabrics are destined to play an important industrial role, and the article on that subject will be of general interest.

Of more than ordinary interest is the article on the necessity for research in the oil-shale industry. Mr. GAVIN speaks for the Bureau of Mines, which is conducting investigations of a fundamental character both as to the technology of shale oil and the best type of retort. It is quite evident that science will have an

opportunity to contribute largely to the establishment of this industry. In suggesting experiment with the Scotch retort Mr. GAVIN takes a stand in opposition to other authorities, but his line of reasoning involves building a new industry on past experience. Low-temperature carbonization of coal presents a number of problems which are discussed by Dr. CURTIS. The byproducts from this treatment, consisting of mixtures of paraffine and coal-tar bodies, present problems which will require scientific knowledge for their solution.

This wide range of industries would have been still further expanded by appropriate articles on the future rôle of chemistry in food production, fertilizer manufacture and ceramics had the authors not been unavoidably delayed in their work. These articles we hope to present in subsequent issues. The omission from this issue of the market reports, price lists and other miscellaneous items is caused by the large number of contributions and the necessity for conserving paper.

Chemical Warfare Post Of the American Legion

ONE of the important meetings to be held during the week of the Chemical Exposition will be that of the Chemical Warfare Post of the American Legion. On the evening of Sept. 22 in the Conference Room of the Grand Central Palace it is planned to effect a permanent organization, membership being open to all C. W. S. ex-service men. The new Post should be vigorously supported by those who are eligible to membership, not only for purposes of sociability but for the perpetuation of traditions of the service and assistance to General FRIES and his organization.

The Origin of Signs and Symbols

IT WAS EDMONDO DE AMICIS, we believe, who said that at Constantinople ten thousand people tread the bridge across the Golden Horn every day, but that an idea crosses it only once in ten years. And we wonder how often in our modern affairs we bring ideas from the past over the bridge of scholarship?

If we look into the history of chemistry we find it clearly divided into periods of progress. We cannot well go back of THALES of Miletus (about 640-550 B.C.), who was rather a mathematician than a chemist, although from him we have the postulate that water is the source of all things. He lived on an island, he is said to have been a business man, and it was he who introduced *abstract* geometry, the object of which is to establish precise relations between the different parts of a figure. It seems, however, beyond doubt that in the eighth century B.C. there were astronomical observatories in most of the cities of the Valley of the Euphrates, so that there was great learning and study before his day. The only trouble is that we have lost the threads of it. Plane geometry THALES is said to have learned from Egyptian priests. ANAXIMENES and LEUCIPPUS were a bit younger, but were contemporaries of THALES and also citizens of Miletus. They proposed air and earth as the substantial elements. HERACLITUS of Ephesus came a little later (540-475 B.C.) but was probably born before ANAXIMENES and LEUCIPPUS died, and he maintained that fire was the primordial thing. Before him it was ZOROASTER (660-583 B.C.), who followed still earlier philosophers, antedating even the Chaldeans, from whom ABRAHAM sprang, in regard to the supremacy of fire. It was of these pre-Chaldean teachers that a profound scholar now dead told the writer many years ago that they had left this record: "We worship GOD, and GOD only. We hold the sun to be His symbol, because from it come both light and heat; moreover, in it are contained all the elements of the earth."

EMPIDOCLES (490-430 B.C.) proposed earth, air, fire and water as the four elements of matter, and DEMOCRITUS of about the same time originated the atomic theory. Water, he said, was liquid, because its atoms are smooth and round and can easily glide one over another. A solid like iron, he contended, must be made up of atoms which are hard and rough. ARISTOTLE (384-322 B.C.) made the distinction between what he called the matter and the essence of a substance. If it had not been for the ecclesiastical commentators on ARISTOTLE, who claimed supernatural control of that which is intangible, we might have concluded that he foreshadowed chemical energy and latent heat and that he foretold radioactivity. But even if he did he probably didn't know it. ARISTOTLE also noted that wine yielded an inflammable substance.

ARCHIMEDES (289-212 B.C.) and ERATOSTHENES (276-194 B.C.) addressed themselves rather to hydrostatics and mechanics, and there followed PLINY the Elder (23-79 A.D.), who enjoyed the friendship of emperors and was a delightful old gossip, writing down everything he could read or learn. His Natural History is a joy to this day, even if it is grotesquely wrong in almost every respect. It is beautifully translated, and we know of no more fascinating book for the idle hours of a man of science. Then darkness was upon the earth.

The next glimpse of light seems to have been reflected originally from Egypt, but brought into Europe along about the eighth century by the Arabs. They had the idea of a *materia prima*, present in all things, but always contaminated by impurities. By many processes of purification, especially by fire, it was hoped to obtain the true "essence" or "tincture," and this was substantially the philosopher's stone which could work miracles. But our pious forbears would have none of this ungodly thinking. The learned Arabs were put to death whenever this was possible, because they were unbelievers, and therefore in league with SATAN. Their books were burned. The only idea that was acceptable was the plan to get rich quick by turning baser metals into silver and gold, and this also was under lively suspicion of dæmonic origin. It continued through mediæval and renaissance days, and some of the alchemistic symbols were designed to represent the planets supposed to be associated with various metals. Others were empirical marks made to hide the meaning of the writers lest they be held guilty of the high crime of Inorthodoxy.

Alchemy developed into iatrochemistry, or medical mysticism, which began with PARACELSUS, who was born in 1493, and the symbols were still in use when America was discovered. They were not always the same; many were invented and used by individuals as cipher, but an interesting number of them have come down to us. We have used a few for the cover of this issue, from which we modestly think it may be observed that they lend themselves especially to decorative purposes. The meanings of those shown on our cover, beginning at the upper left-hand corner and reading to the right are: Gold, earth, silver, copper, vitriol, sulphur, salt, air, water, fire, mercury, lead, tin and iron.

Cleanliness In the Plant

A CONTRIBUTOR to FRANKLIN P. ADAMS' "Conning Tower" column of the New York *Tribune* writes as follows: " . . . As I see more and more of benighted Japan I recall with an involuntary shudder a journey through Kansas last spring—Kansas, the richest community on earth, with a bleak environment of derelict outbuildings, faded 'homes' of bald and hideous architecture, lawns conspicuous by infrequency, and right-angled white schoolhouses. I wonder what strange psychology prompts the Japanese peasant, crowded and illiterate, . . . to build him a picturesque little cottage, as neat inside as a new cigar box, surrounded by shrubbery and a priceless garden. And I wonder what instinct prompts the wife to array herself in classically artistic fashion, and to attire her offspring in like manner. In Kansas the stranger closes his eyes; in Japan he rarely encounters anything to affront them."

We do not know why the author selected Kansas for his comparison; there are plenty of other states that would have served equally well. But his point is well taken; we Americans are very low in the scale of artistic conscience. We are practical in a utilitarian sense, but we are among the least practical of peoples in æsthetics. In our own field of industry we probably rank below the farmer in this respect. Chemical works are notoriously ugly, and ugliness of structure and surroundings is one of the principal enemies to cleanliness, to order, to comfort in living, and to the pleasant things of life. Hygienic equipment and baths are excellent in their way, but they do not go all the way. If we learn that a chemical factory is to be built in the neighborhood where we live, we are usually disposed to move away if we can; we fear that it will stink; and we have good reason to believe that it will have a dirty, messy entrance and neglected grounds about it.

We know that, inside the works, cleanliness and not only convenient but pleasant arrangements are worth while. The outside we regard as not important, and here we are wrong. The outside *is* important. Every man and woman that works for us is impressed by appearances as he or she enters our portals. It is not necessary that these be conscious impressions. Psychology and experience both teach us that it is the persistent repetition of impressions that counts large in determining the direction of our thoughts and the mold of our opinions. The worst billboard offenders know this, and make it the very basis of their offenses. For instance, if some enterprising tobacconist plasters the walls and fences of the town with advice to smoke his Mercaptano cigars, we may not be disposed to smoke them, but all unconsciously we find ourselves asking for a couple of Mercaptanos when we step in at the cigar store to buy a smoke.

The stranger that passes by registers an impression of us, whether he knows it or not, if only he casts a glance at our works. This impression is either that as a corporate entity we are ugly and dirty and that we stink, or that we look well and agreeable and pleasant. In order that the latter rather than the former opinion be registered as to our persons, most of us bathe diligently, shave every day, wear clean linen, have our boots polished and do what we can to produce what we call a "good" impression. We may say we don't care what people think, but usually in our hearts we know this is not so. So long as we are beyond the pinch of poverty, even shabby clothes are more likely than not to be a studied carelessness to give the impression of affability with all sorts and conditions of men.

If, then, we would have our persons create an agreeable impression, there is abundant reason why our works should do likewise. True, a proper care for and pride in the exterior of our plant increase the overhead charges, and overhead charges are not popular, especially if they can be avoided. But overhead charges are as necessary as fuel or a sales department. A vast amount of administrative wisdom lies in discrimination as to overhead. Old Uncle DAN'L DOLLARDOODLE, who doesn't know or care for anything but dividends, wants to cut out all "deadwood," as he calls it, as soon as he comes on the board of directors and begins to debilitate the company. He condemns the library, the research laboratory, the testing plant and the gravel walks and sod. He condemns everything on which he does not see a crop of immediate dividends growing. And usually he ruins the business. We recognize the presence of infinitely minute quantities of certain bodies which we cannot analyze, and yet which make or mar our products by their presence. Now, there are intangible qualities that also hold good in regard to the outside of the works. The effect of beauty or ugliness is silent but persistent. In what we do we represent the application of science which, for the welfare of all, we need to introduce into life. History, it is claimed, must be rewritten in the light of science, in the light of man's conquest of nature, rather than according to the might, the battles and the whimsies of kings. The day is dawning when the opinion of men of science is asked in regard to public affairs, and science, like other vocations, is known by its works. The factory is properly called the works. Men of science have a greater public responsibility today than ever before. So far as industrial chemists are concerned, how do their works appear? In the great majority of cases they look like the devil.

Radioactivity as the Possible Cause of Heartbeat

BELATED information from Holland reveals researches which Professor ZWAARDEMAKER has been making into the physiological effects of radioactivity. In some highly interesting experiments with solutions of radioactive metals on isolated frog hearts previously brought to a standstill with potassium-free Ringer's solution, the ingenious professor has coaxed the vital organs into renewed pulsations. Perfusion with solution of radioactive elements in proper dosage restored the heartbeat, whereas none of the non-radioactive elements did so. Dr. ZWAARDEMAKER also discovered that the absence of radioactive element in the kidney allows the passage of sugar and throws the muscular wall of the arterioles out of action, while normal activity is restored by the addition of a radioactive element.

Somehow we cannot help regretting that the eminent doctor made his discoveries. Life is becoming so complex that there seems to be no rest for the weary. After, as has been the habit of some of us, talking so much and saying so little about vitamines, both water-soluble and fat-soluble, must we now begin to worry about our radioactive rations? Must those of us who may be of diabetic propensity now prepare to take a mesothorium cure?

Program of the Exposition

Symposia Prepared by the Exposition Management on Fuel Economy, Industrial Management, Materials Handling, Chemical Engineering, and Ceramics—Motion Pictures Illustrating a Wide Range of Industrial Chemical Operations

FOLLOWING is the program of the Sixth National Exposition of Chemical Industries, to be held at the Grand Central Palace, New York City, Sept. 20 to 25:

Monday, Sept. 20

8 P.M.

Opening address by Charles H. Herty.

"Co-operation in the Industries," Charles L. Reese.

Sir George E. Foster, Canadian Minister of Trade and Commerce, will speak.

"Problems Confronting the American Exporter," Erastus Hopkins (Gaston, Williams & Wigmore, Inc.).

Followed by motion pictures:

1. "The U. S. Ammonium Nitrate Plant No. 2 at Muscle Shoals." (2 reels.) (Courtesy Dwight P. Robinson & Co.)
2. "Modern Packaging Methods." (4 reels.) (Courtesy Pneumatic Scale Corporation.)

Tuesday, Sept. 21

2 P.M.—FUEL ECONOMY SYMPOSIUM

Chairman's Address, R. C. Beadle (Managing Editor, *Combustion*).

"Burning Coal at 100 Per Cent B.t.u. Efficiency," W. O. Rankin (Quigley Furnace Specialties Co.).

"Saving Fuel by Controlling Chimney Losses," F. F. Uehling (Uehling Instrument Co.).

"Fluid Heat Transmission," Alexander B. McKechnie (Parks-Cramer Co.).

"Producer Gas and the Modern Mechanical Producer," W. B. Chapman (Chapman Engineering Co.).

"Refractory Cement: Life Insurance for a Furnace," F. W. Reisman (Quigley Furnace Specialties Co.).

"Preventing Conduction and Radiation Heat Waste," S. L. Barnes (Armstrong Cork Co.).

"Increasing Conduction and Reducing Fuel Consumption," W. R. Van Nortwick (The Roto Co.).

"The Reason for the Fuel Saving in the Dressler Kiln," Conrad Dressler (American Dressler Tunnel Kilns, Inc.).

8 P.M.—MOTION PICTURES

Great U. S. chemical industries:

1. "The Story of Sulphuric Acid." (1 reel.) (Courtesy General Chemical Co.)
2. "The Production of Salt for the Chemical Industry." (1 reel.) (Courtesy International Salt Co.)
3. "Perfumes for the World." (Courtesy Antoine Chiris Co.)
4. "A New Chemical Industry: Leather From the Ocean: Fish Leather." (3 reels.) (Courtesy Ocean Leather Co. and Ford Educational Film Co.)

Wednesday, Sept. 22

2 P.M.—INDUSTRIAL MANAGEMENT SYMPOSIUM

"Ultra Analysis of Costs," Harrington Emerson (The Emerson Engineers).

"Research in Industrial Conservation," H. E. Howe (Chairman, Division of Research Extension, National Research Council).

"Progress of the American Coal-Tar Industry," Grinnell Jones (U. S. Tariff Commission).

3 P.M.—MATERIALS HANDLING SYMPOSIUM

Chairman's Address, Roy V. Wright (Editor, "Material Handling Cyclopedia").

"Material Handling: The Paramount Problem," J. H. Leonard (Editor, "Freight and Terminal Engineering").

"Chain Power Transmission," F. G. Anderson (Morse Chain Co.).

"Steel Collapsible Shipping Containers as Related to the Chemical Industries," Everett W. Morgan (Pneumatic Scale Corporation).

8 P.M.

Meeting of Chemical Warfare Post.
(Speakers to be announced.)

Thursday, Sept. 23

2 P.M.—CHEMICAL ENGINEERING SYMPOSIUM

(Meeting of the American Institute of Chemical Engineers, David Wesson, Chairman.)

"A New Method of Destructive Distillation," Thomas W. Pritchard (Fuel Products Corporation).

"Nitration of Hydrocarbons," A. Hough and W. Savage.

"Recoverance: A Physical Property in Material and Its Importance," Robert G. Guthrie (Widney Test Laboratories).

"Operating Data of a Modern Byproduct Coke Oven Plant," C. R. Bellamy.

"Canada and the Chemist," C. Price-Green (Canadian National Railways).

"Utilization of Peat" (illustrated), B. F. Haanel (Canada Department of Mines).

"Corrosion of Iron and Steel as Affecting the Industries," W. D. Richardson (Swift & Co.).

6:30 P.M.

Dinner of American Institute of Chemical Engineers at the Technology Club.

8 P.M.—MOTION PICTURES

Great U. S. chemical industries:

1. "Modern Coke and Gas Manufacture." (3 reels.) (Courtesy The Koppers Co.)
2. "The Story of Petroleum Oil." (3 reels.) (Courtesy Standard Oil Co. of New Jersey.)

3. "The Asphalt Paving Industry." (1 reel.) (Courtesy Barber Asphalt Paving Co.)
4. "Colloidal Movement in Asphalt." (1 reel.) (Courtesy Barber Asphalt Paving Co.)

Friday, Sept. 24

2 P.M.—CERAMIC SYMPOSIUM

(Meeting of the American Ceramic Society, R. H. Minton, Chairman.)

"The Meaning Attached to the Term 'Ceramics' in Ancient and Modern Usage." Committee Report, Condensed.

"A Classification of Sheet Steel Enamels," R. R. Danielson, (U. S. Bureau of Standards.)

8 P.M.—MOTION PICTURES

Mining industries:

1. "The Story of Coal." (4 reels.) (Courtesy Sullivan Machinery Co. and U. S. Bureau of Mines.)
2. "Building, Mining and Quarrying Machinery." (2 reels.) (Courtesy Sullivan Machinery Co.)
3. "Producing Pumps and Engines." (1 reel.) (Courtesy Midwest Engine Co.)
4. "Silver Mining in Ontario." (1 reel.)
5. "Gold Mining in Ontario." (1 reel.) (Courtesy Ontario Department of Mines).
6. "The Manufacture of Pottery." (1 reel.) (Courtesy American Ceramic Society).

Saturday, Sept. 25

2 P.M.

Speakers to be announced.

8 P.M.—MOTION PICTURES

1. "Manufacture of Asbestos." (1 reel.)
2. "Silks and Satins." (2 reels.) (Both by Courtesy Bureau of Commercial Economics.)
3. "Foamite Firefoam Extinguishing Apparatus at Work." (1 reel.) (Courtesy Foamite Firefoam Co.)
4. "Continuous Motion, Conveying, Stacking, Elevating, Loading and Unloading Machinery." (1 reel.) (Courtesy Brown Portable Machinery Co.)
5. "The U. S. Ammonium Nitrate Plant No. 2 at Muscle Shoals, Alabama." (2 reels.) (Courtesy Westinghouse-Church-Kerr, Inc.)

Exhibitors at the Exposition

A Brief Description of the Exhibits of Over Four Hundred Exhibitors Prepared for the Exposition Visitor Who Wishes to Conserve His Time and Make Certain of Seeing Those Things in Which He Is Most Interested

THE following societies and publications have reserved booths for reception and social purposes where they will be glad to receive their friends.

AMERICAN CHEMICAL SOCIETY.
AMERICAN DYESTUFF REPORTER.
AMERICAN DYES INSTITUTE.
AMERICAN ELECTROCHEMICAL SOCIETY.
AMERICAN FERTILIZER.
CANADIAN CHEMICAL JOURNAL.
CANADIAN MINING JOURNAL.
CANADIAN TEXTILE JOURNAL.
CHEMICAL AGE.
CHEMICAL & METALLURGICAL ENGINEERING.
CHEMICAL CATALOG.
CHEMICAL COLOR AND OIL DAILY.
COLOR TRADE JOURNAL.
COMBUSTION.
CONTAINER CLUB.
IRON AND STEEL OF CANADA.
JOURNAL OF COMMERCE.
JOURNAL OF INDUSTRIAL AND ENGINEERING CHEMISTRY.
MANUFACTURERS RECORD.
OIL, PAINT AND DRUG REPORTER.
PAPER MILL AND WOOD PULP NEWS.
PULP AND PAPER MAGAZINE OF CANADA.
TEXTILE COLORIST.
TEXTILE WORLD JOURNAL.
TEXTILES.

The following list of exhibitors at the Sixth National Exposition of Chemical Industries, together with a brief statement of their exhibits and names of representatives, will be of special value to those who expect to attend the Exposition. Being published well in advance, it will enable prospective visitors to conserve their time and give attention to those matters in which they are particularly interested. The list is practically complete. Where no description of exhibit is given, the information requested either was not furnished or arrived too late for publication. No attempt has been made to give booth numbers or location in the Grand Central Palace, because these will be more easily obtained from the handbook and guide which will be distributed at the Exposition with our compliments.

ABBE ENGINEERING CO.—Ball mills, pebble mills, laboratory grinding machines, disintegrators, rotary cutters for roots, herbs, rubber, etc.; bolting cloth. In charge of exhibit: H. F. Kleinfeldt.

ABBE, PAUL O., INC.

AINSWORTH, WM., & SONS.—Precision analytical and assay balances; precision analytical balance with keyboard-operated weight carrier for handling fractional gram weights. Precision assay balance with a sensitivity of 1/1000 mg.; readings are indicated by a reflected beam of light. In charge of exhibit: Robert G. Ainsworth.

AJAX ELECTROTHERMIC CORP.—Laboratory induction furnace with vacuum tube; brass tube annealing furnace; brass-melting furnace for materials of melting point not above 1,550 deg. C. In charge of exhibit: Edwin F. Northrup, Dudley Willcox and Harry F. Porter.

ALBERENE STONE CO.—Exhibit of laboratory construction of Alberene stone, consisting of a typical fume hood, wall table with reagent shelves, sink, peg-board, etc. In charge of exhibit: E. L. Collins, W. K. Fields, R. G. Grothe, W. Heins, A. Y. Meeker and N. N. Moneypenny, Jr.

ALCOHOL PRODUCTS CO.

ALEXANDER, W. H.

ALLEN ELECTROLYTIC CELL CORP.—The Allen-Moore electrolytic cell. In charge of exhibit: Kent R. Fox and Howard D. Marsh.

ALLIS-CHALMERS MANUFACTURING CO., INC.—Dust collector, motors, rubber-lined centrifugal pump, pulverator. In charge of exhibit: Representatives from the New York office.

AMERICAN ANILINE PRODUCTS, INC.—Full line of colors dyed on felt, leather, wool, cotton and silk. Line of essential oils and fine chemicals. In charge of exhibit: Messrs. Fenton, Gossen, Roelofs, Mehnen, Bennefield, Giroward, Collins, Chase, O'Hara, Hennessy, Whyte, Greegor, McDermott, Schleicher and Cheesman.

AMERICAN CHEMICAL & MFG. CO.

AMERICAN CHEMICAL & SUGAR MACHINERY CO.—Patent multiplex film evaporator and McLaurin patent gas scrubber. In charge of exhibit: Messrs. Lawrence and Dunglinson.

AMERICAN CYANAMID CO.—Illuminated wall case showing models of the principal apparatus used in the fixation of atmospheric nitrogen, and the intermediate and finished products of the cyanamide process. In charge of exhibit: E. J. Pranke, R. R. Stewart and J. P. Hubbell.

AMERICAN DRESSLER TUNNEL KILNS.—Illuminated screen showing continuous view of tunnel kilns and their application to chemical processes; samples of materials such as bricks, porcelain, steel, and malleable iron which have been treated in tunnel kilns. In charge of exhibit: Conrad Dressler.

AMERICAN HARD RUBBER CO.—Hard rubber equipment for handling acids, alkalis, dyes, food products and corrosive chemical solutions. A hard rubber pump will be shown in operation. In charge of exhibit: A. M. Ackerman.

AMERICAN KRON SCALE CO.—Automatic dial scales. In charge of exhibit: John J. Kelly.

AMERICAN LAFRANCE FIRE ENGINE CO., INC.—Industrial safety devices, fire prevention apparatus, chemical engines and fire extinguishers. In charge of exhibit: H. J. Lovell and James W. Knoblock.

AMERICAN METAL CO., LTD.—Ores and products of zinc, molybdenum, lead, copper, gold, silver, arsenic, selenium; sulphuric acid. In charge of exhibit: H. M. Burkey, E. K. Judd, R. C. Latz and Miss A. M. Stout.

AMERICAN METAL PRODUCTS CO.—Acid-resisting castings and finished parts such as valves and cocks; shafting, sheet, rods. Souvenirs will be presented to purchasing agents and engineers, consisting of chisels of 84 per cent copper with which steel may be chipped. In charge of exhibit: R. W. Alger and C. J. Zaiser.

AMERICAN PULVERIZER CO.—American pulverizers suitable for the chemical industry. In charge of exhibit: Dunning, Luckel Engineering Co.

AMERICAN ROLLING MILL CO.

AMERICAN STEEL & WIRE CO.—Sulphate of iron, both sugar and crystal form; different materials made from sulphate of iron or in which this plays an important part in manufacture. In charge of exhibit: Arthur S. Lutz.

AMERICAN TRANSFORMER CO.

AMERICAN WATER SOFTENER CO.

ANACONDA COPPER MINING CO.—Products and byproducts from the smelting and refining of copper ores; electrolytic zinc; uses of copper in the chemical industry illustrated by equipment loaned for the occasion; Anaconda white lead. In charge of exhibit: S. Skowronski.

ANACONDA LEAD PRODUCTS CO.

ANACONDA ROLLING MILL DEPT.

ANGEL, H. REEVE, & CO.—Filter paper of American manufacture; rubber tubing, glass wool, etc. In charge of exhibit: B. S. Proper and T. L. Harrocks.

ANILINE DYES & CHEMICALS, INC.

ANILINE SALES CORP.

ANTHRAKONE DYE PRODUCTS & CHEMICAL CO.

ANTI-HYDRO WATERPROOFING CO.—Liquid chemical compound for rendering concrete waterproof, dustless, oil-proof, acid resisting and chemical resisting. In charge of exhibit: B. A. Meyer, Thomas Moore, Joseph Meyer, M. R. Duffy, M. E. Townsend, Charles A. Brown.

APEX CHEMICAL CO.—Antimony sulphide and other antimony compounds; sulphonating oils, softening, finishing compounds, etc., for the textile industry; chemical specialties for the leather industry; fabrics and leather which have been treated by these specialties.

ARKELL SAFETY BAG CO.—Complete line of "Arksafe" elastic paper linings for shipping packages, plain and waterproofed. In charge of exhibit: Pedro J. Morales.

ARMSTRONG CORK CO.—Nonpareil insulating brick for furnaces, boiler settings, kilns and other high temperature equipment; Nonpareil high-pressure insulation for steam lines, and other hot surfaces; Nonpareil cork covering for brine and ammonia lines and other cold surfaces; Nonpareil corkboard for cold storage rooms or wherever constant temperature is required. In charge of exhibit: Representatives from New York office.

ARNOLD, HOFFMAN & CO., INC.—Oils, softeners, gums, starches, pigment and other colors for textile sizing, printing, and finishing, and for use in the paper, chemical, leather and other industries. In charge of exhibit: H. H. Hall, C. L. Berntson, E. M. DeBaun, G. D. Curtis, H. P. Geier.

ATERITE CO., INC.—Aterite-trimmed valves and cocks for handling petroleum; Aterite valves, cocks and fittings for high temperature stills and sulphuric acid lines; also valves and fittings for all temperatures of steam, both saturated and superheated. Wrought Aterite in the shape of rods, sheets, wire, etc. In charge of exhibit: Ernest G. Jarvis.

ATLANTIC DYESTUFF CO.—The central feature will be a miniature dye-making plant, in addition to which the company will show its various products. In charge of exhibit: Charles H. Stone, G. R. Stoettner, H. M. Paine, H. R. Ullrich, C. C. Burt and Karl Ruger.

ATLAS ELECTRIC DEVICES CO.—Color Fade-ometers for color testing by standardized radiation. In charge of exhibit: Clarence W. Jameson and Hugh E. Weightman.

BABBITT, B. T.

BACHARACH INDUSTRIAL INSTRUMENT CO.—Pressure recorders and gas meters in actual operation; special demonstration showing the application of Pitot tube to the measurement of gases. In charge of exhibit: Herman H. Sticht, Mr. Lauterbach, and Mr. Bacharach.

BACHMEIER & CO.—Aniline dyes. In charge of exhibit: G. M. Lord, William Baur and H. L. Gettler.

BAILEY METER CO.—Working exhibit of meters for water, steam, gases, and various chemicals. In charge of exhibit: E. G. Bailey, W. R. Little, H. M. Hammond, N. Dmytrow, Jr. and M. Repa.

BAKER, J. G., CHEMICAL CO.

BARBER ASPHALT PAVING CO.—Comprehensive exhibit of native lake asphalts and their products, with special reference to those useful in chemical plants and laboratories. Crude and refined asphalt, mineral rubber, ready roofing, asphalt shingles, preservative paints, high-grade oils for special lubricating purposes, flotation oils.

BARRETT CO., THE—This company has joined forces with the General Chemical Co., the National Aniline & Chemical Co., the Semet-Solvay Co. and the Solvay Process Co. in a series of booths containing an instructive and educational exhibit of their products. In charge of exhibit: H. G. Sidebottom.

BAUSCH & LOMB OPTICAL CO.—Metallographic equipment, consisting of large photomicrographic camera with special microscope designed for metallographic work; optical measuring instruments such as the Duboscq colorimeter, Abbe & Dipping refractometer and saccharimeter, chemical microscope and binocular microscope. In charge of exhibit: E. H. Anthes, I. L. Nixon and W. L. Patterson.

BEACH-RUSS CO.—The following machines will be shown in operation: High-duty vacuum pumps, rotary air compressors, laboratory pumps, acid pumps and heavy liquid pumps. In charge of exhibit: Howard C. Russ.

BEAVER CHEMICAL CO.—Sulphur colors. In charge of exhibit: John E. Rooney and John B. Dunbar.

BECKER, CHRISTIAN, INC.—Analytical and laboratory balances, featuring the chainomatic balances; bullion scales; torsion balances. In charge of exhibit: W. C. Symington, A. T. Millroy and J. W. Wetz.

BECKLEY PERFORATING CO.

BETHLEHEM FOUNDRY & MACHINE CO.—Wide range of castings of Corrosiron. Demonstration by acid test of a comparison of the wearing qualities of Corrosiron against cast iron. In charge of exhibit: J. George Lehman, R. E. Wilbur, A. H. Stevens, R. H. Stevens and George Ettele.

BLACKMER ROTARY PUMP CO.—Models of pumps, with necessary explanatory charts and pictures of the various units made. In charge of exhibit: A. L. Rock and F. P. Goertz.

BLACKSTON'S SON, P., & CO.

BOOTH ELECTRIC FURNACE CO —Booth rotating brass furnace of 500-lb. capacity. In charge of exhibit: C. H. Booth, E. F. Tweedy and F. W. Doran.

BOYER OIL CO., INC.—Vegetable oils such as castor, coconut, cotton, mustard, palm, rape and sunflower, together with the seeds from which they are made and typical byproducts. In charge of exhibit: Messrs. Boyer, Kienle, Blythe, Weber and others.

BRISTOL CO.—Full line of recording and indicating instruments for pressure and vacuum, liquid level, temperature, electricity, time, motion, speed. In charge of exhibit: H. L. Griggs.

BROWN INSTRUMENT CO.—Comprehensive display of indicative and recording pyrometers, recording and resistance thermometers, indicating and recording instruments for pressure, vacuum, speed, time and operation. In charge of exhibit: J. D. Andrews, M. A. Leister, George W. Goodman, R. B. McCafferty, C. D. Porterfield and O. W. Stowe.

BROWN PORTABLE CONVEYING MACHINERY CO.—Portable inclined elevator for piling boxes, bags and bales. Portable inclined elevator for loading and elevating loose material. Hand power portable tiering machine for lifting and piling cases, rolls and drums. In charge of exhibit: O. H. Oertel

BUCKMAN & PRITCHARD, INC.—Exhibit of refractory shapes, bricks, cupola blocks and crucible high tension insulators and spark plug cores of zirconium silicate or zircon. Commercial products of ilmenite and rutile, including a newly developed white pigment. In charge of exhibit: George A. Pritchard and H. H. Buckman.

BUFFALO FOUNDRY & MACHINE CO.—Vacuum drying apparatus, evaporators, chemical equipment and sugar apparatus. New developments during the past year in Buflovak and Buflokast apparatus. In charge of exhibit: E. G. Rippel.

BURRELL TECHNICAL SUPPLY CO., INC.—Burrell gas analysis apparatus and other testing apparatus. In charge of exhibit: G. H. Burrell, R. P. Mase and H. J. Segrave.

CALCO CHEMICAL CO.—Dyes and intermediates with demonstration of dyeings on fabrics, paper pulps and lakes. In charge of exhibit: Messrs. Sampson, Sumner, Klein, Bosworth, Ackerman, Paradies and Merry.

CALIFORNIA ALKALI CO.

CANADA CARBIDE CO.

CANADIAN ELECTRODE CO.

CANADIAN ELECTRO PRODUCTS CO., LTD.—Carbide of calcium, acetic acid, acetaldehyde, paraldehyde, U. S. P. and commercial and aldehyde ammonia. In charge of exhibit: H. E. Mussett, Henry Booth and J. C. Fruit.

CANADIAN PACIFIC RAILWAY CO.

CARBORUNDUM CO.—Crude carborundum and aloxite crystals; silicon metal; carborundum and aloxite abrasive products, such as grain, abrasive paper, cloth and wheels; carborundum refractory brick and special shapes; silfrax pyrometer protection tubes and muffles. In charge of exhibit: Otis Hutchins, Dr. Hartman, S. C. Linbarger, C. E. Hawks and W. L. Meek.

CARRIER ENGINEERING CORP.—Complete installation of Carrier humidifying equipment in operation, and typical products into the manufacture of which Carrier equipment enters. In charge of exhibit: J. E. Bolling.

CELLULOID ZAPON CO.

CENTRAL SCIENTIFIC CO.—Constant temperature apparatus consisting of electrically heated and controlled drying ovens, vacuum ovens and water baths; high vacuum pumps; electrically operated laboratory devices; electric furnaces and electro-titration apparatus; oil and fuel testing equipment; physicochemical apparatus. In charge of exhibit: S. L. Redman, O. T. Lewis and A. B. Carter.

CHADWICK-BOSTON LEAD CO.

CHAPMAN ENGINEERING CO.—Automatic floating agitator complete with automatic feed in actual operation. Regulating and recording devices in actual operation on pressure and vacuum lines. In charge of exhibit: W. B. Chapman.

CHAPMAN VALVE MFG. CO.

CHEMICAL CO. OF AMERICA, INC.—Dyes and intermediates. In charge of exhibit: S. Iserman, Chas. Kendall, A. P. Christ, R. H. Steele and F. X. Lehmann.

CHEMICAL EQUIPMENT CO.—Ceco products, comprising acid valves and pumps, priming systems, spray systems, experimental vacuum evaporator. All except the latter will be in operation. In charge of exhibit: H. E. LaBour, R. T. White, F. L. Dunlap and E. M. Baker.

CHEMICAL PUMP & VALVE CO.—Centrifugal pumps, packingless valves and fittings for chemical works. In charge of exhibit: A. B. Antisell, F. A. Warter.

CHIRIS, ANTOINE, CO.—Full line of essential oils, synthetic aromatic chemicals, resinaromes, oleo resins, etc.; manufactured in American factories. Also a full line of products from the company's French factories; capes-viscose, a self-fixing bottle capping.

CLEVELAND-CLIFFS IRON CO.—Refined wood chemical products; methyl alcohol, methyl acetone, acetone, acetic acid, hexamethylenamine, etc. In charge of exhibit: Charles B. Hall, Austin Farrell and E. J. Hudson.

CLEVELAND INSTRUMENT CO.—Thermo-electric and resistance types of indicating and recording pyrometers; multiple station circular chart recorder. In charge of exhibit: Herman H. Sticht, W. B. North and H. B. Rich.

CLINCHFIELD PRODUCTS CORP.—Feldspar, ground and crude; variety of finished articles using this material. In charge of exhibit: Charles Ingram and Leo L. Hunt.

CLIPPER BELT LACER CO.—Three different types of clipper belt lacing machines; demonstration of belt lacing. In charge of exhibit: William F. Kall.

COMMERCIAL SOLVENTS CORP.

CONSOLIDATED CHEMICAL PRODUCTS CO.

CONTACT PROCESS CO.—Sulphuric, muriatic and nitric acids, fuming sulphuric acid, oleum, mixed acid, salt cake. In charge of exhibit: Dr. von Rucker and T. Smith.

CORNING GLASS WORKS.—Complete line of Pyrex laboratory glassware and apparatus. In charge of exhibit: G. Willis Drake, Frederick Kraissl, Irving B. Cary, F. F. Pfeiffer and A. S. Eggleton.

CRANE CO.

CRANE PACKING CO.—Full line of "John Crane" flexible metallic packings for liquid, vapor and acid service. Demonstration of electrolytic disintegration of tubes and pipes, with methods of packing to avoid this destruction. In charge of exhibit: Julian N. Walton and F. E. Payne.

CRESCENT SALES & ENGINEERING CO.—Crescent roto-piston vacuum and pressure pumps, Crescent vacuum chucks. In charge of exhibit: L. L. Beeken.

DAVIDSON, M. T., CO.—Steam pumps for general power plant service and for acid. In charge of exhibit: John Lowe and William E. Brennan.

DAVISON CHEMICAL CO.—Pyrites ore, cinders, sinter, copper precipitate, sulphuric acid, acid phosphate, double superphosphate, magnesium fluosilicate, precipitated silica and silica gel. A working exhibit showing the absorbent qualities of silica gel. In charge of exhibit: E. B. Miller, B. F. Lovelace, Walter A. Patrick, W. D. Huntington, J. R. Wilson and A. E. Marshall.

DELAVAL SEPARATOR CO.

DENVER ENGINEERING WORKS CO.

DERMATOLOGICAL LABS.

DETROIT ELECTRIC FURNACE CO.—Detroit electric furnaces for melting brass, bronze, copper, aluminum, cast iron and steel alloys. In charge of exhibit: E. L. Crosby, E. L. Kavanaugh, H. M. St. John and A. E. Rhoads.

DETROIT RANGE BOILER & STEEL BARREL CO.—"Perfect" metal bilge barrels, black and galvanized; Detroit drums both light and heavy type with removable head. In charge of exhibit: W. B. Goddard, C. C. Choate, H. Ross Mack.

DEVINE, J. P., CO.—Display of vacuum apparatus, such as drum driers, chamber driers and vacuum pumps; also an exhibit of "Kek" pulverizing mills. In charge of exhibit: J. P. Devine, C. P. Devine, L. W. Graves, E. H. Miller and H. C. Mills.

DIAMOND STATE FIBER CO.—Vulcanized fiber in sheets, rods, tubes, cans, sample cases, trunks; condensite celoron waterproofing insulation. In charge of exhibit: Charles M. Bogert.

DINGS MAGNETIC SEPARATOR CO.—Three magnetic separators in operation for the treatment of material which may be submitted. In charge of exhibit: J. R. Manegold, E. S. Hirschberg, J. E. Randall, S. G. Oates and A. H. Ackerman.

DOMINION WATER POWER BRANCH OF THE DEPARTMENT OF THE INTERIOR OF OTTAWA, CANADA.—This bureau will be in charge of engineers qualified to give general and particular information concerning Canada's water-power and economic minerals, both of which are important in the establishment and development of the chemical industry in Canada. In charge of exhibit: J. B. Challies, J. P. Johnston and A. M. Beale.

DORR CO., THE—Working installation of Dorr agitator, tray thickener and pump demonstrating methods of mixing and dewatering applicable to chemical and industrial processes; small working models of Dorr equipment. The special feature will be a miniature sewage treatment plant. In charge of exhibit: P. M. McHugh, H. N. Spicer and H. W. Morgan.

DOW CHEMICAL CO.—Chemicals: pharmaceutical, industrial, heavy; dyes; intermediates; insecticides. In charge of exhibit: G. Lee Camp, Leland I. Doan, Ralph E. Dorland, George Ashworth and Wilson I. Doan.

DRACKETT, P. W., & SONS CO.

DRAPER MFG. CO.

DRYING SYSTEMS, INC.—Small drier for the chemical industry. In charge of exhibit: F. A. Lippert, C. H. Currier and R. E. Lippert.

DUNNING, LUECKEL ENGINEERING CO.—Nelson wood plate and frame filter press for corrosive liquids. American ring pulverizer for pulverizing lime stone, pyrite, salt, phosphate rock, etc. In charge of exhibit: Harry Dunning, W. J. Lueckel and Paul S. Knittle.

DU PONT DE NEMOURS, E. I., & CO.—This company will exhibit products of the following divisions: Lithopone, dry colors and pigments division, chemical products division, acids and heavy chemical division and dyestuffs sales division. Special attention will be given to the display of dyes.

DURIRON CASTINGS CO.—Comprehensive selection of Duriron apparatus, covering standardized designs of regular equipment and new equipment. First showing of the industrial film "The Story of Duriron." In charge of exhibit: Messrs. Schenck, Pitman, Hall, Dart, Pratt, Smith, Daniels, Elkins, Suverkrop, Jaffe, Schatzabel, H. H. Van Etten and O. Jacobsen.

EAGLE PICHER LEAD CO.—Display of lead products, and products of other industries in which lead is used; a model of a sublimed white lead (basic sulphate) plant. In charge of exhibit: H. Gates, A. F. Brown, C. E. Gilson, L. E. Kelly and J. R. MacGregor.

EAST JERSEY PIPE CO.—The centrifugal and extractor department will exhibit a Hercules-Electric hydro extractor and a 7-in. working model machine of the same design. In charge of exhibit: H. H. Stephens.

EASTMAN KODAK CO.—Organic chemicals for research purposes; Eastman tested chemicals for photographic use; exhibits of a physical and photographic nature from the research laboratory.

ECONOMIC MACHINERY CO.

ECONOMY ENGINEERING CO.—Miniature oil warehouse containing economy steel barrel racks and tiering machines; full-size electrically driven tiering machines; full size hand power tiering machines; one unit economy steel barrel rack, full size. In charge of exhibit: T. R. Tordoff.

EDGAR BROS. CO.

EGYPTIAN LACQUER MANUFACTURING CO.—Lacquers, thinners, enamels and similar products, as well as finished articles on which these products have been used. In charge of exhibit: Messrs. Sopher, DeBaun, Popper, Hayward, Henry and Schlott.

EIMER & AMEND—Replaceable unit electric furnaces and hot plates; Freas electric ovens; Hortvet cryoscope; Juerst ebullioscope; Bingham & Green viscometer and plastometer; McMichael viscosimeter; U. S. Navy type emulsifier; Barnstead water still; Wysor polishing and grinding apparatus; Braun pulverizer; Morgan drop weight apparatus; American rotary vacuum pump; MacLeod gage, Columbia University type; Kobe condenser; Fleming and Fisher combustion bulbs; Hortvet butter fat bottle; refractometers; microscopes and Duboscq colorimeters. In charge of exhibit: C. G. Amend, W. R. Eimer, F. Wilbur Schulenberger, Theodore Taistra, I. Banner and Herman Weber.

ELECTRIC FURNACE CO.

ELECTRO BLEACHING GAS CO.—Finished products which have required the use of liquid chlorine in the process of their manufacture. In charge of exhibit: James B. Duggan, S. W. Jacobs, S. I. Escoett, W. A. Kennedy and George R. Ellis.

ELECTROLYTIC ZINC CO., INC.

ELECTRON CHEMICAL CO.—Allen-Moore electrolytic cell. In charge of exhibit: Kent R. Fox and Howard D. Marsh.

ELMORE, G. H.—Elmore continuous centrifugal machine in operation. In charge of exhibit: G. H. Elmore and R. W. Rigler.

ELYRIA ENAMELED PRODUCTS CO.—Elyria enameled stills, autoclaves, open-jacketed tilting kettle complete with agitator, still complete with condenser, receiver and pump. The autoclave and the multiple unit condenser, which will be shown with the 10-gal. still, are entirely new developments. In charge of exhibit: Wm. E. Gray, Wm. E. Gray, Jr., Max Donauer and R. W. Smith.

EMPIRE LABORATORY SUPPLY CO., INC.—Chemical glassware and apparatus; laboratory supplies of all kinds. In charge of exhibit: M. A. Goldstein, E. C. Weiskopf, H. L. Thompson, J. C. Headley, P. Freedman and H. Freedman.

ENGELHARD, CHARLES—Indicating and recording pyrometers, automatic temperature regulators, electric furnaces, impervite refractories, pyrometer tubes, transparent quartz glass, electric resistance thermometers, mercury vapor arc lamps. In charge of exhibit: C. W. Hubbard.

EVERLASTING VALVE CO.

EXCELSIOR DYESTUFFS & CHEMICAL CO.—Dyes and chemicals. In charge of exhibit: Walter Reinicke and Charles Frankel.

FALCON DYE & CHEMICAL CO., INC.—Aniline colors. In charge of exhibit: Dr. E. C. Altvater, Harry Laut and Julius Oettinger.

FLEISHER, W. L., & CO., INC.—Air-conditioning apparatus and a spray drier. In charge of exhibit: W. L. Fleisher, A. W. Lissauer and D. L. Connelly.

FLORASYNTH LABORATORIES—Raw materials for flavoring extracts, flavoring extracts and other aromatic chemicals; betanaphthol benzoate and benzyl benzoate medicinal. In charge of exhibit: Louis A. Rosett, Charles L. Senior and Alexander Katz.

FOAMITE FIREFOAM CO.—Fire extinguishers of the smaller type using foamite and firefoam, with demonstration of the effectiveness of these extinguishers in smothering fire. In charge of exhibit: R. H. Austin.

FOOTE MINERAL CO.—Display of rare and unusual ores, together with chemical products manufactured from the same. A feature of the exhibit will be the demonstration of the refractory properties of zirkite and zirkonalba in the electric furnace. In charge of exhibit: H. C. Meyer and Samuel K. Bell.

FOXBORO CO., INC.—Recording and indicating instruments for pressure and vacuum, hydraulic gages, combinations of recording thermometer and temperature controller. CO_2 recorder in operation, and other instruments. In charge of exhibit: W. W. Patrick and E. P. Grout.

FUEL PRODUCTS CORP.

GARRIGUE, CHAS. F., CO.

GARRIGUE, WILLIAM, & CO.—Oils, fats, glycerine and soaps in various stages of processing. In charge of exhibit: J. W. Bodman, O. H. Wurster and W. E. Sanger.

GEIGY CO., INC.

GENERAL BAKELITE CO.—Bakelite materials with examples of their various applications; operation of molding press giving demonstration of the bakelite molding process. In charge of exhibit: Hylton Swan, H. S. May, L. M. Rossi, C. H. Hall and William S. Gordon, Jr.

GENERAL BRIQUETTING CO.—Briquets made from fine fuels and fine chemical and metallurgical byproducts. In charge of exhibit: A. L. Stillman, J. Sprung and J. E. Stevens.

GENERAL CERAMICS CO.—Models of standard chemical stoneware apparatus consisting of a complete plant for the manufacture of muriatic acid which will be operated at intervals during the exposition; chemical stoneware exhaust fan and an etching machine which will be operated as required: fused silica shapes made at the company's new plant near Perth Amboy, N. J. In charge of exhibit: Percy C. Kingsbury, F. A. Whitaker and R. S. Beecher, A. C. Otto, Hubert Royer and K. J. Peters.

GENERAL CHEMICAL CO.—Working model of the latest type sulphuric acid tank car; 5-ton model of the new Herreshoff for roasting ores, in operation daily; display of reagent chemicals. In charge of exhibit: Messrs. A. W. Hawkes, G. G. Ackerson, C. E. Shean, George N. Vardy, J. H. Eberhardy, M. M. Biddison, J. E. Wilson, R. P. Silva, W. J. Kramer and J. L. Thomas.

GENERAL ELECTRIC CO.

GENERAL FILTRATION CO., INC.—Filtros uniformly porous, acid-proof, artificial stone, filter plates in various shapes and sizes; Filtros acid-proof cement, and acid-proof stoneware girders. In charge of exhibit: F. E. Leiby and W. W. Robacher.

GENERAL FIRE EXTINGUISHER CO.

GEORGIA LEAD WORKS.

GIBSON PRICE & CO.

GLAMORGAN PIPE & FOUNDRY CO.—Working model of continuous gas-fired limekiln and standard flaking and congealing machine; nine compartment filters and standard Duplex exhauster. In charge of exhibit: C. H. Hinnant.

GLASS COATING CO.

GLENS FALLS MACHINE WORKS—Demonstration of rotary sulphur furnace for production of SO_2; model of a Knot & Silver screen for use on either chemical or mechanical wood pulp. In charge of exhibit: Harold D. Wells and Fred S. Chaffee.

GORDON DRYER CORP.—Gordon high-efficiency atmospheric-type drier for drying chemicals, colors, dyestuffs, pharmaceutical and medicinal products. In charge of exhibit: Nathan Owitz, N. W. Park and John Bogge.

GOTTESMAN, M., & CO., INC.—Industrial chemicals for the paper and pulp industry, such as sulphate of soda, sulphate of alumina, bleaching powder, china clay, casein, rosin, blanc fixe and soda ash. In charge of exhibit: Arthur J. Sigel, Guy A. Gardner and E. A. Pita.

GOULDS MANUFACTURING CO.—Line of pumping machinery suitable for use in chemical plants. In charge of exhibit: W. H. Hopper, H. R. Gumbert, W. H. Valentine, W. J. O'Neill, H. J. Angell and E. E. Brereton.

GREELEY PRODUCTS CORP.—Lubricating, vegetable, fish and animal oils, pine products and industrial chemicals. In charge of exhibit: H. A. Carman, H. S. Kenyon, W. R. Boin and B. D. McCampbell.

GREINER, EMIL, CO.—Chemical and scientific instruments and apparatus made of glass. In charge of exhibit: Emil Greiner, Emil Vonhof, P. Todtschinder and M. Kohn.

GRINNELL CO., INC.—Grinnell automatic sprinkler and other Grinnell fire-protection devices. The Grinnell automatic sprinkler will be shown in operation periodically throughout the exposition. In charge of the exhibit: Howard E. Branch, Frank V. Sackett, F. S. Crans, Henry Walsh and Robert Nicholson.

GROCH CENTRIFUGAL FLOTATION, LTD.

GRUENDLER PATENT CRUSHER & PULVERIZER CO.

GUERNSEYWARE CO.—Complete line of chemical laboratory porcelains consisting of crucibles, casseroles, evaporating dishes, beakers, combustion boats, mortars and pestles, porous cells, etc. In charge of exhibit: Allan L. Goulding.

HAMILTON & HANSELL, INC.—Illustrations of electric-furnace installations. Information on general metallurgical processes such as ore dressing, smelting, chloridizing and leaching processes in accordance with the Ramen patents. Models of flue cleaners. In charge of exhibit: H. A. De Fries.

HANOVIA CHEMICAL & MANUFACTURING CO.—Electric resistance furnaces, quartz resistance thermometers, Hanovia quartz mercury arc lamp, transparent quartz laboratory ware and Engelhard pyrometers. In charge of exhibit: A. L. Schweickart, E. Simonds, G. H. Wilson, Leon Witmondt, R. W. Newcomb and C. W. Hubbard.

HARDINGE CO.—Hardinge conical ball and pebble mills for metallurgical, chemical and industrial crushing and grinding, either wet or dry. In charge of exhibit: W. H. Baker, R. B. T. Killiani, Harlowe Hardinge, James G. Parmelee, G. F. Metz and S. R. Swain.

HAUSER-STANDER TANK CO.—Tank of red gulf cypress lined with chemical lead with joints burnt in by hand; vacuum filter tank of long leaf yellow pine; methods of construction of wooden tanks. In charge of exhibit: S. Hauser, Jr. and D. B. Dorfan.

HAYNES STELLITE CO.

HAYS, JOSEPH W., CORP.

HAYWARD, S. F., & CO.

HEPWORTH, S. S., CO.—Mackintosh electrically-driven centrifugal in operation. In charge of exhibit: C. A. Olcott, E. Foster Babbitt and George Fred Brindley.

HERCULES ENGINEERING CORP.

HERCULES POWDER CO.—Dummy explosives, soluble cotton wet with water and soluble cotton solutions; naval stores. In charge of exhibit: W. M. Annette and G. C. O'Brien.

HEROLD CHINA & POTTERY CO.—Complete line of chemical and scientific porcelain ware. In charge of exhibit: H. F. Coors.

HEYL LABS. INC.

HEYDEN CHEM. CO. OF AMERICA

HOOKER ELECTROCHEMICAL CO.

HOSKINS MANUFACTURING CO.—Electric laboratory and tool furnaces, indicating and recording pyrometers and chromel heat-resistant castings. In charge of exhibit: W. D. Little, Charles S. Kinnison, F. L. Zimmerman, A. L. Malmstrom and J. E. Hines.

HOYT METAL CO.

HUFF ELECTROSTATIC SEPARATOR CO.—Operating exhibit of the Huff electrostatic separator and Olumb pneumatic jig. A special feature of the exhibit will be the separation of ash and sulphur from coal.

HUNTER DRY KILN CO.

HUYCK, F. C., & SONS—Woolen filter cloth. In charge of exhibit: D. A. MacInnes, E. A. Rees and A. V. Wright.

HYDROCARBON CHEMICAL CO.

IDEAL STENCIL MACHINE CO.

IMPERIAL DYEWOOD CORP.

INDEPENDENT CHEM. CO.

INDUSTRIAL ELECTRIC FURNACE CO.—New type of electric melting furnace for operation on a 220-volt d.c. motor circuit. In charge of exhibit: F. von Schlegell, W. B. Cooley, L. C. H. Groeger and W. B. Lewis.

INDUSTRIAL FILTRATION CORP.—Zenith continuous rotary filter, Zenith continuous rotary hopper dewaterer and Zenith open-tank type filter. The Zenith rotary filter will be in operation in connection with a complete filtration unit for this type of apparatus. In charge of exhibit: William H. Harding, G. D. Dickey, H. W. Conrad and A. W. Wright.

INNIS SPEIDEN & CO., INC.

INTERNATIONAL CARBON PRODUCTS CO.—Graphite and graphite products which have been electrically refined by the Huff electrostatic process.

INTERNATIONAL COOPERAGE CO.

INTERNATIONAL NICKEL CO.—Monel metal, natural nickel alloy, resisting alkalis, most acids, superheated steam, high temperatures and corrosion. In charge of exhibit: E. S. Wheeler, T. H. Dauchy and F. H. Waycott.

INTERNATIONAL SALT CO. OF NEW YORK—Salt in all grades. In charge of exhibit: H. J. Osborn.

IRVING IRON WORKS CO.—Irving-subway metallic flooring and safstep. In charge of exhibit: W. E. Irving, F. L. Price, H. H. Schuldt, A. S. Kennedy and W. H. Lown.

JEWELL POLAR CO.—Water-distilling apparatus, operated by steam, gas and electricity. In charge of exhibit: A. C. Jewell, J. E. Bloeser and P. M. Marks.

JOPLIN WHITING CO.

KALBFLEISCH CORPORATION—General line of mineral acids, some of the allied salts and products particularly interesting to paper manufacturers. In charge of exhibit: A. C. Kalbfleisch, V. P. Davis and C. L. Hutzelman.

KENART SYNTHETIC PRODUCTS CO.

KEWAUNEE MFG. CO.

KING CHEMICAL CO.

KLIPSTEIN, A., & CO.

KNIGHT, MAURICE A.—Acid-proof chemical stoneware apparatus, selected to convey a good idea of the use of this material in chemical industry. In charge of exhibit: Maurice A. Knight, Charles Dennison, Samuel J. Baril and Newton D. Whipple.

KNOXVILLE BOARD OF COMMERCE—Natural raw materials in vicinity of Knoxville, suitable for use in electrochemical and electrometallurgical industries. In charge of exhibit: Harry Clark, John A. Switzer, Walter McIntyre, H. A. Morgan, M. F. Nichols, Charles A. Weller, J. N. Newman and W. R. Pouder.

KOPPERS CO.—Sectional model of Koppers triangular-flued combination coke and gas ovens; photographs of byproduct coke and gas plants. In charge of exhibit: E. L. Crowe and C. R. Meissner.

LAKEWOOD ENGINEERING CO.

LAMIE CHEMICAL CO., INC.—Dyes and chemicals. The feature of the exhibit will be Flaming Red, a new dyestuff used in the paper and silk industry. In charge of exhibit: K. E. Schlossingk.

LAMMERT & MANN CO.—Lammert rotary vacuum pumps, for vacuum or pressure. In charge of exhibit: A. L. Eisenbies, Donald Rosie and R. F. Lammert.

LAUREL SOAP MANUFACTURING CO.—Textile soaps, sizing and finishing material.

LEAD LINED IRON PIPE CO.—Galvanized lead-lined iron pipe, flanged lead-lined valves and fittings, screwed lead-lined fittings, tin-lined iron pipe and fittings. In charge of exhibit: Daniel H. Regan and Frank H. DuBois.

LEEDS & NORTHRUP CO.—Electrical measuring instruments for chemical and metallurgical processes. Features of the exhibit will be: equipment for demonstrating the Hump method for heat treatment of steel; optical and thermocouple pyrometers, including equipment for automatic recording, signaling and control; outfit for electrometric determination of hydrogen ion concentrations; recording and controlling Wheatstone bridge for electrolytic conductivity work; automatic recording and controlling potentiometer for regulating amount of reagent added in an acid-alkaline reaction. Most of the exhibits will be in actual operation. In charge of exhibit: Paul E. Klopsteg, A. M. Redding, I. M. Stein, R. D. Milner, George W. Tall, Jr., G. H. English and E. B. Estabrook.

LIBERTY BY-PRODUCTS WORKS, INC.—Compounds of antimony and chromium; lactolin, soaps and oils. In charge of exhibit: E. A. F. Zillessen, E. J. Zillessen, W. H. Zillessen, August Naab, Jr., A. Washington and P. B. Meerbott.

LINDSAY LIGHT CO.—Display of salts of the rare earths. In charge of exhibit: Dr. McCoy, A. Sinai and Otto N. Berndt.

LIQUID CARBONIC CO.

LOOMIS-MANNING FILTER DISTRIBUTING CO.—Standard filters and a filter in section showing interior construction and details; glass working model showing operation. In charge of exhibit: George H. Powell.

LUNGMOTOR CO.—The Lungmotor for resuscitation in cases of apparent drowning, asphyxiation, electric shock, narcotic poisoning, strangulation and collapse during anæsthesia. In charge of exhibit: L. D. Jones and Max Jacobson.

LUNKENHEIMER CO.—Valves in bronze, iron and cast steel suitable for various operating conditions and for pressures up to 350 lb. per sq.in. and a temperature of 800 deg.; engineering specialties.

LUZERNE RUBBER CO.—Hard rubber pipe, fittings, buckets, and special parts for the chemical industry. In charge of exhibit: H. E. Case.

MAAS & WALDSTEIN CO.—Wood and metal work showing applications of clear lacquer and lacquer enamel finishes; lacquer and lacquer enamels in glass containers. In charge of exhibit: Harry C. Flannigan.

MAGNESIA ASSOCIATION OF AMERICA—Samples of different kinds of 85 per cent magnesia; diagrammatic chart showing

manufacture in process; miniature samples of 85 per cent magnesia products. In charge of exhibit: C. J. Stover, G. S. Stuart.

MAGNETIC MANUFACTURING CO.—Demonstration of a laboratory-size high-intensity magnetic separator for such ores and minerals as may be offered for treatment. In charge of exhibit: J. P. Bethke.

MANN & COOK.

MATHIESON ALKALI WORKS, INC.—Caustic soda, soda ash, Virginia soda, bicarbonate of soda, bleaching powder, liquid chlorine, chlorine solvents; materials produced from these products. In charge of exhibit: John A. Kienle, John W. Boyer and G. N. Davis.

MEAD & CO.—Mead mills, featuring a laboratory mill. In charge of exhibit: Paul O. Abbe.

MERCK & CO.—Medicinal chemicals and blue label reagent chemicals.

MERRILL CO.—Merco Nordstrom plug valve. In charge of exhibit: C. C. Broadwater, L. D. Mills, F. H. Ricker, H. P. MacGregor and S. J. Nordstrom.

METALS DISINTEGRATING CO., INC.—Zinc dust, lead dust, tin dust, copper dust, litharge. In charge of exhibit: S. G. Schatzberg.

MIDLAND CHEMICAL CO.

MIDWEST ENGINE CO.—In charge of exhibit: F. L. Atwood, D. I. Smith, R. C. Palmer, G. A. Drysdale.

MINE & SMELTER SUPPLY CO.—Wilfley concentrating table, Ruth flotation machine, Dourte valveless pump in operation; Samson laboratory jaw crusher, McCool pulverizer, Heusser balances. In charge of exhibit: E. S. Tompkins and J. C. Beam.

MINER-EDGAR CO.—Cotton solutions for coating split and artificial leathers; solvents for cotton and celluloid; wood alcohol, acetone, methyl acetone; prepared clays for paper and paint manufacturers. In charge of exhibit: Rolland H. French, J. J. Smith, Charles H. Zeiger, George N. Bick, John W. Johnson.

MINE SAFETY APPLIANCE CO.

MINERAL POINT ZINC CO.

MOBILE & OHIO RAILROAD CO.

MOJONNIER BROS. CO.

MONARCH MANUFACTURING WORKS, INC.—Brass, iron, hard rubber and stoneware sprays, for use in sulphuric acid manufacturing plants; lead valves; lead siphons; oil burners, and an automatic acid elevator, which when attached to existing acid eggs elevates acid to any desired height automatically.

MONEL METAL PRODUCTS CORP.—In booth with International Nickel Co., showing monel metal. In charge of exhibit: H. F. Chase and H. A. Cooper.

MONO CORP. OF AMERICA—Automatic recording instruments for analyzing CO_2, CO, SO_2; recorder for oxygen and hydrogen. In charge of exhibit: F. D. Harger and Olaf Rodhe.

MORSE CHAIN CO.—Samples of chains, showing the Morse rocker joint, from ¼ in. pitch to 3 in. pitch and in several widths illustrating the chain as used for ¼ hp. to 5,000 hp. In charge of exhibit: T. G. Anderson, H. W. Evans, A. B. Wray, V. D. Morse, J. S. White, E. R. Morse and H. M. Rodda.

MOTT, J. L., IRON WORKS.

MULTI METAL CO., INC.—New U. S. standard sieve series; wire cloth screens and filter cloth in unusual weaves, meshes and metals. In charge of exhibit: Siegfried Stern, Frederick Stern, Selmar Pullman and Louis Dresner.

NASH ENGINEERING CO.—Hytor compressors and vacuum pumps in operation; Jennings pump, motor and turbine driven, for handling combinations of liquid and gas. In charge of exhibit: Irving C. Jennings, H. M. Wylie and G. B. Wright.

NASSAU VALVE & PUMP CORP.— Chemetal acid-resisting valve and centrifugal pumps. In charge of exhibit; A. T. Haviland, E. J. Walsh, H. C. Evans and C. Schmitt.

NATIONAL ANILINE & CHEMICAL CO.—Scene of wax figures costumed in the latest modes and artistically grouped on the piazza of a country house. All the materials used in this scene will be dyed with the "National" colors. The central setting will be flanked on either side by exhibits of the company's technical products.

NATIONAL BINDING MACHINE CO.

NATIONAL FILTER CLOTH & WEAVING CO.

NATIONAL GUM & MICA CO.—Pulp and other colors; permasol marking ink, crayons, etc.; synthetic perfume bases; adhesives. In charge of exhibit: Messrs. Alexandre, Namy, Harris, Adrizonne and N. A. McManus.

NATIONAL LAMP WORKS.

NELSON, ALFRED W.

NEWARK WIRE CLOTH CO.—Wire and wire cloth, chemists' testing screens, monel metal filter cloth; loom for weaving in operation. In charge of exhibit: A. A. Campbell and E. C. Nichols.

NEW ENGLAND TANK & TOWER CO.

NEW JERSEY ZINC CO.—Flow sheet showing developing of zinc ore into finished products; display of zinc products and descriptive literature. In charge of exhibit: W. Homer Hendricks and S. T. Ballinger.

NEWPORT CHEMICAL WORKS, INC.

N. Y. COLOR & CHEMICAL CO.—Dyes and colors for the textile, paper, leather and lake trades. In charge of exhibit: Messrs. Williams, Jacquith, Taylor, Carter, Richmond, Staneck and Wardlaw.

NEW YORK CONTAINER CO., INC.

NIAGARA ALKALI CO.—Caustic potash, caustic soda, bleach powder, permanganate of potash and muriatic acid.

NIAGARA ELECTRO CHEMICAL CO.

NICHOLS COPPER CO.

NITROGEN PRODUCTS CORP.—In charge of exhibit: J. C. Clancy and A. Nagelvoort.

NITRO PRODUCTS CO.—H acid. In charge of exhibit: W. H. Van Winckel and H. D. Wellmann.

NORTHWESTERN CHEMICAL CO.—Organic esters, salts and acids; synthetic flavoring materials. In charge of exhibit: Robert L. Wilson and Henry J. Beck.

NORTON CO—Representative shapes of laboratory ware and larger refractories made from alundum and crystolon; grinding wheels and abrasive grain; electrically fused magnesia. In charge of exhibit: C. W. Saxe and R. Kirkpatrick.

OBERMAYER, S., CO.—Hott-Patch furnace cement for power and chemical plants. A small electric furnace will be used for demonstration of the product. In charge of exhibit: E. D. Frohman, John L. Cummings, H. E. Beckman and J. M. Hildebrand.

OLIVER CONTINUOUS FILTER CO.—A small size Oliver continuous filter in operation. In charge of exhibit: R. G. Walker, H. A. Morrison, P. M. Depp and W. A. V. Thomsen.

ONTARIO DEPARTMENT OF MINES—Representative ores and minerals from the province of Ontario, with special attention to gold, silver and nickel-copper. Smelter and refinery products will also be shown. In charge of exhibit: W. K. McNeill and W. R. Rogers.

ORGANIC SALT & ACID CO.—Salicylic acid, sodium salicylate, salol, methyl salicylate, acetyl salicylic acid, and other salicylates. In charge of exhibit: Karl Kolbe.

OXYGEN PRODUCTS CO.

OZONE CO. OF AMERICA—Apparatus showing the application of ozone to the purification of water and to the bleaching and deodorizing of liquids for industrial purposes; household ozone water purifier; ozone air ventilators; industrial and therapeutic uses of ozone. In charge of exhibit: William J. Eberle and C. O. Riedel.

PALO CO.—Laboratory supplies and apparatus; filter paper, automatic water stills, Goerz polariscopes, Zeiss microscopes and refractometers, Meker furnaces and burners, Hess-Ives tint photometer, rhotanium. In charge of exhibit: L. A. Phluger and M. J. Seavy.

PARKS-CRAMER CO.—Completely assembled Merrill process system of fluid heat transmission, available for easy inspection; principal parts of the Cramer air-conditioning system. In charge of exhibit: Albert W. Thompson, Alexander B. McKechnie, Thayer Francis and Frank G. Bell, Jr.

PAYNE, STEPHEN T.

PENNSYLVANIA SALT MANUFACTURING CO.—Mineral acids, alums, alumina, lye, gas purifiers, caustic soda and soda products, sulphate of alumina for paper and color making, filtration, dyeing and tanning, chloride of lime, liquid chlorine, chloride of alumina, aluminate of soda and zirconia, Greenland kryolith. In charge of exhibit: Messrs. Hutchinson and James.

PERMUTIT CO.—Demonstrating outfits of Permutit water softeners and filters; photographs and drawings of commercial-size apparatus. In charge of exhibit: A. T. Smith, R. W. Epple, M. F. Corin, J. S. Shedden and C. L. Boyd.

PERRY & WEBSTER, INC.—Consulting and designing engineers, formerly Kalbperry Corp., specializing in design of chemical plants; photographs of varnish plants, using new system of fume recovery. In charge of exhibit: Robert S. Perry, Paul W. Webster and Vern K. Boynton.

PERTH AMBOY CHEMICAL WORKS.

PETERSON, LEONARD, & CO.—Laboratory furniture for industrial laboratories and educational institutions.

PFAUDLER CO.—Acid-resisting fittings for use with the company's glass-enameled steel equipment; glass-enameled steel products. In charge of exhibit: P. S. Barnes, J. A. Cowles, R. L. Jacobs and T. D. Wilson.

PHILADELPHIA DRYING MACHINERY CO.—Three types of driers: Cabinet tray, tunnel truck tray and continuous apron. In charge of exhibit: B. P. Webster.

PHILADELPHIA QUARTZ CO.—Silicate of soda in its various forms, and its application in industry. In charge of exhibit: John D. Carter, C. F. Wolcott, W. H. Buxton, George W. Wait and R. C. Brown.

PITTSBURGH-DES MOINES STEEL CO.

PNEUMERCATOR CO., INC.—Various models of liquid measuring devices. In charge of exhibit: H. S. Parks and William Thomas.

PNEUMATIC SALES CORP., LTD.

PORETE MFG. CO.

POWER SPECIALTY CO.—Uses of superheated steam in the chemical industry and the special developments of the Foster superheater for chemical manufacturers.

POWERS REGULATOR CO.—Automatic temperature regulators for hot water tanks, dyeing and bleaching machines; automatic water mixers, steam and water mixers, steam pressure reducing valves and other automatic temperature control apparatus. In charge of exhibit: H. W. Feige, F. A. Murray and O. F. Weilbacker.

POWHATAN MINING CO.—Exhibit of Powminco asbestos filter fiber; demonstration showing uses of product in the laboratory. In charge of exhibit: Fred A. Mett.

PRATT ENGINEERING & MACHINE CO.

PRECISION INSTRUMENT CO.—CO_2 and SO_2 recorders; single, 2 in 1 and 3 in 1 recorders; gas meters, gravitometers and calorgraphs; single, 2 in 1, 3 in 1, 4 in 1 and 5 in 1 gages, flue gas analyzers and micrometer gages.

PROCTER & GAMBLE DISTRIBUTING CO.—Industrial soap, glycerine, stearic acid, red oil, pichene and stearine pitch. In charge of exhibit: T. E. Watters, H. G. Werner, J. D. O'Farrell, J. D. Cochrane, L. C. Minor and J. O. Pierce.

PROCTOR & SCHWARTZ, INC.—Proctor 12-tray laboratory drier; models of Proctor 3-conveyor drier for cotton, hair, wool, etc., and of Proctor 3-truck drier for chemicals, colors, etc.; samples of chemicals, colors, etc., dried in Proctor driers; projectiscope in operation showing Proctor drier installations. In charge of exhibit: E. B. Ayres, H. S. Landell, D. D. Hollenbaugh, E. A. Hults, C. W. Schwartz, 3d, S. Rhoads and Mrs. A. E. Reiter.

PROTECTO SAFETY APPLIANCE CO.

PROVOST ENGINEERING CORP.—Mixing machinery. In charge of exhibit: C. A. Beach.

PYROLECTRIC INSTRUMENT CO.—Pyrometric and electrical precision instruments, including Northrup pyrovolter, Compton electrometer, galvanometers, etc. A new type of resistance box and several other new instruments will be shown for the first time. In charge of exhibit: W. C. Harter and Harry L. Saums.

QUIGLEY FURNACE SPECIALTIES CO.—Furnace refractories; hytempite, for bonding firebrick and granular refractories; carbosand for furnace linings and repairs; insulbrix, for insulating furnace walls; heat-treating and powdered coal equipment. In charge of exhibit: W. S. Quigley, H. A. Kimber, J. H. McPadden, W. O. Renkin, F. W. Reisman, H. H. Harris, P. F. McGovern and C. Gantzman.

RARITAN ANILINE WORKS.—Aniline oil. In charge of exhibit: W. H. Van Winckel, H. D. Wellman and A. B. Hamby.

RARITAN COPPER WORKS.—With Anaconda Copper Mining Co.

RAYMOND BROS IMPACT PULVERIZER CO.—Quarter-size models of the principal types of pulverizing machines in operation. In charge of exhibit: C. M. Lauritzen, F. I. Raymond, Joe Crites, S. B. Kanowitz and W. M. Cook.

RAYMOND LEAD WORKS.

REFINITE CO.

REPUBLIC FLOW METERS CO.—Steam, water, air and gas flow meters; low differential gas meter, Gebhardt portable indicating steam meter, CO_2 recorders, orifices and Pitot tubes. In charge of exhibit: T. A. Curran and George S. Hendrickson.

RESEARCH CORP.

REVOLVATOR CO.—Revolving and non-revolving, hand-power and motor-driven revolvators.

RHODIA CHEMICAL CO.

RICHARDS CO.

ROBERTSON HAMES LEAD WORKS.

ROBINSON, DWIGHT P., & CO., INC.

ROESSLER & HASSLACHER CHEMICAL CO., LTD.—Chloroform, cyanide, metal cyanides, trisalyts, formaldehyde, hexamethylenetetramide, antimony salts, soda prussiate, metallic sodium and sodium peroxide, supplemented by a general line of chemicals. The special feature of this exhibit will be methyl chloride. In charge of exhibit: Herbert Gillis.

ROLLIN CHEMICAL CORP.—Barium, sodium and chlorine products. In charge of exhibit: J. G. Harrison.

ROTO CO.

RUGGLES-COLES ENGINEERING CO.—Model of drier and photographs of the installations. In charge of the exhibit: F. E. Finch, J. K. Towers and W. H. Glomb.

SARCO CO., INC.—Steam traps, radiator traps, temperature control apparatus, recording gas calorimeters and CO_2 recorders. In charge of exhibit: E. J. Ritcher, G. W. Bergen and others.

SCHAAR & CO.—Complete line of American-made laboratory apparatus and supplies; Schaar analytical balances. In charge of exhibit: A. E. Schaar and E. W. Ohman.

SCHAEFFER & BUDENBERG.—Recording thermometers and gages; a new type of thermometer not hitherto shown. In charge of exhibit: H. V. Carlier, F. Undeutsch and A. Campbell.

SCHWARTZ SECTIONAL SYSTEM.—Sectional filing cabinets for chemicals, reagents, samples and specimens; Schwartz auxiliary desk and chemistry desk. In charge of exhibit: M. P. Schwartz.

SCIENTIFIC EQUIPMENT CO.—Representative line of American-made laboratory furniture and apparatus, as manufactured and sold by the Kewaunee Manufacturing Co. and the Central Scientific Co. In charge of exhibit: J. M. Roberts, S. L. Redman, A. B. Carter, Charles G. Campbell, O. T. Louis, R. S. Blodgett and Charles Ress.

SCOTT, ERNEST, & CO.—Photographs of machinery and apparatus installed by the company for the extraction of oils from nuts, seeds, tankage, fish waste; photographs of Scott evaporator for recovery of glycerine, caustic soda, paper pulp spent liquors, etc.; photographs of vacuum driers; plants for manufacture of ammonia, distilling fatty acids, manufacture of glycol and glycerine. In charge of exhibit: H. Austin, R. W. MacGregor and C. E. Bradley.

SCOTT, HENRY L., & CO.

SEMET-SOLVAY CO.

SEYDEL MFG CO.—Benzoates for medicinal use; furamine dyes. In charge of exhibit: Edmund E. Smith.

SEYMOUR & PECK CO.—Wooden shipping drums for dry chemicals. In charge of exhibit: C. B. Arnold.

SHARPLES SPECIALTY CO.—Models of laboratory and commercial super-centrifuges. In charge of exhibit: Max B. Miller, Aldus Wilbur and Homer Cloukey.

SHAWINIGAN ELECTROMETALS CO.

SHAWINIGAN PRODUCTS CO.

SHAWINIGAN WATER & POWER CO.

SHERWIN-WILLIAMS CO.

SIDIO CO. OF AMERICA, INC.—Complete line of fused silica ware made in America, for laboratory and industrial purposes. In charge of exhibit: Francis H. Ruhe, Walter J. Fensterer, and G. H. Mueller.

SIMMONS, JOHN, CO.

SLY, W. W., MFG. CO.—Operating unit of a dust-collecting, reclaiming and air-purifying system. In charge of exhibit: D. E. Hadley, E. J. Moore and M. M. Lowrie.

SOLVAY PROCESS CO.

SOUTHERN COTTON OIL CO.

SOUTHERN OIL & CHEMICAL CO.

SOUTHERN RAILWAY SYSTEM.

SOWERS MFG. CO.—Operating exhibit consisting of Dopp seamless steam jacketed mixing kettles with different styles of agitators; Dopp seamless jacketed kettle arranged for oil heating; Dopp laboratory vacuum pan. In charge of exhibit: R. C. Boggess and others.

SPARKS, JOHN C.

STAMFORD DYEWOOD CO.

STAUFFER CHEMICAL CO.

STEIN, HALL & CO., INC.—Starches, gums and dextrines. In charge of exhibit: L. W. Peabody.

STERLING CHEMICAL CO.

STICHT, HERMAN A., CO.

STIMPSON EQUIPMENT CO.—Mitchell electric vibrating screen and miniature Janney flotation machine. In charge of exhibit: C. W. Stimpson, J. E. Klein and J. A. Lane.

STOKES, F. J., MACHINE CO.—Stokes rotary tablet machine in operation making naphthaline balls; powder filling machine in operation; rotary vacuum drier, laboratory

shelf vacuum drier, copper vacuum still, vertical surface condenser, automatic water still. In charge of exhibit: L. H. Bailey and C. F. Coleman.

STURTEVANT MILL CO.—Open-door ring roll mill, swing sledge mill and steel elevator; consultation on problems of crushing, grinding, pulverizing, screening, mixing, elevating, and conveying. In charge of exhibit: L. H. Sturtevant, W. T. Doyle and H. A. Tomlinson.

SULLIVAN MACHINERY CO.—Operating model of air-lift pump showing the application of the air-lift principle to the pumping of liquids. In charge of exhibit: John Oliphant, L. R. Chadwick and L. E. Gilbert.

SUNBEAM CHEMICAL CO.

SWENSON EVAPORATOR CO.—Two experimental size evaporators. In charge of exhibit: F. M. deBeers, P. B. Sadtler, G. Gordon Urquhart and F. F. Mackentepe.

TABER PUMP CO.

TAGLIABUE, C. J., MFG. CO.—Witham controllers for maintaining uniform temperature in paper machine driers; P & W condensate controller and liquid level controller. In charge of exhibit: Messrs. White, Dooling, Traudt, Dougherty and Wichum.

TAKAMINE COMMERCIAL CORPORATION.

TAKAMINE LABORATORY, INC.—Chemicals: arsaminol, neo-arsaminol, merpotide, merposal, boro tetramine, silver nucleinate, tuyol, hirathiol. In charge of exhibit: Jokichi Takamine, Jr.

TANNER, CHARLES S., CO.—Polyzime, for de-gumming and de-sizing in the textile industry. In charge of exhibit: C. Milton Tanner and William S. Newell.

TAYLOR INSTRUMENT CO.

TECHNICAL PRODUCTS CORP., INC.

TEXAS GULF SULPHUR CO.—In charge of exhibit: A. S. Cosler.

THATCHER PROCESS CO.—Anthraquinone. In charge of exhibit: W. H. Van Winckel, H. D. Wellman and B. Ives Cooper.

THERMAL SYNDICATE, LTD.—Vitreosil, fused pure silica, for acid concentration, cooling and condensation; glazed vitreosil laboratory apparatus; transparent vitreosil tubing and utensils. In charge of exhibit: W. E. Strevig, S. L. Tyler and W. W. Winship.

THERMO ELECTRIC INSTRUMENT CO.—Freas and Thelco constant temperature ovens, incubators and other apparatus for laboratory use. In charge of exhibit: Royal B. Freas, Joseph LaMar and Edwin G. Price.

THOMAS, ARTHUR H., CO.—Laboratory apparatus and supplies. In charge of exhibit: R. M. Miller, H. C. Roak and C. C. Roberts.

THWING INSTRUMENT CO—Temperature recording and indicating apparatus and some new paper testing instruments. In charge of exhibit: C. B. Thwing, E. J. Albert, H. K. Walton, J. H. Torrey and A. S. Hall.

TITANIUM ALLOY MFG. CO.—Ferro-carbon-titanium; opax, commercial zirconium oxide, for use in the manufacture of enameled ware and terra cotta; samples of material in which opax has been used. In charge of exhibit: William J. Evans and William V. Knowles.

TITANIUM PIGMENT CO.—Titanox pigments and various samples of paint, enamels, rubber, oil cloth, wall paper and printing ink in which these pigments have been used. In charge of exhibit: L. E. Barton and C. J. Kinzie.

T. M. & G. CHEMICAL CO.—Diethyl aniline. In charge of exhibit: W. H. Van Winckel, H. D. Wellman and William B. Whitmore.

TOLHURST MACHINE WORKS.—Operating demonstration of a new type of motor-driven suspended centrifugal machine suitable for heavy service in industrial chemical plants; open-top center slung centrifugal; standard self-balancing centrifugal with griddle bottom discharge; solid curb centrifugal with rubber-lined case and rubber covered basket; laboratory centrifugals. In charge of exhibit: W. C. Dutton, T. A. Bryson, John S. Gage, T. M. Stuart, B. M. Pilhashy and R. K. Cheney.

TYLER, W. C., CO.

UEHLING INSTRUMENT CO.—New CO_2 recording instrument for continuous measurement of percentage of CO_2; Uehling pneumatic pyrometer, draft gages and recorders, draft analyzers, pressure gages and recorders. In charge of exhibit: F. F. Uehling, C. J. Schmid, C. C. Phelps, and Wm. J. Reilly.

UNIFORM CHEMICAL PRODUCTS CO., INC.—Benzidine base. In charge of exhibit: W. H. Van Winckel, H. D. Wellman and C. S. Cooley.

UNION STEAM PUMP CO.—Complete pumping equipment for the chemical industry; vacuum and pressure pumps, steam, belt and motor driven. In charge of exhibit: R. W. Friedman, E. P. Ordway and K. D. Smith.

UNION SULPHUR CO.—In charge of exhibit: W. N. Wilkinson.

UNITED FILTERS CORP.—Working model of an American filter; Sweetland and United filter presses and samples of filter press plates and cloths.

UNITED LEAD CO—Chemical lead-lined pipe fittings, valves, tanks; chemical lead-covered coils; hard lead centrifugal acid pumps. In charge of exhibit; C. B. Holden, G. H. Checkley, J. W. Spotten, C. R. Andrews, H. Freiherr and H. F. Hempel.

UNITED METALS SELLING CO

UNITED STATES CAST IRON PIPE & FOUNDRY CO—Barometric counter-current condenser in section with descriptive diagrams of operation; samples of casting for chemical and sugar industry; cast-iron flanged pipe. In charge of exhibit: H. A. Hoffer, J. D. Capron and C. D. Donaldson.

U. S. INDUSTRIAL ALCOHOL CO.—Photographs showing operation of plant; samples representing different stages in the manufacture of alcohol from crude molasses. Copies for distribution of chart showing uses of alcohol; new motor fuel "Alcogas." In charge of exhibit: B. R. Tunison.

UNITED STATES INDUSTRIAL CHEMICAL CO.—New chemical products, some of which have been manufactured in the United States during the past year for the first time. In charge of exhibit: B. R. Tunison.

U. S. SMELTING FURNACE CO.

UNIVERSAL ANILINE DYES & CHEMICAL CO.—Direct colors. In charge of exhibit: Stephen H. Eller.

UNIVERSAL OIL CO.

VALLEY IRON WORKS.—Autoclaves and sulphonators in laboratory and semi-commercial sizes. In charge of exhibit: Messrs. Senior, Mills and Jacobs.

VAN NOSTRAND, D., & CO.

VAN WINCKEL, W. H.—Aniline oil, aniline salt, thiocarbanilid, diethylaniline, H-acid, benzidine base. In charge of exhibit: W. H. Van Winckel and H. D. Wellman.

VITREOUS ENAMELING CO.

VULCAN DETINNING CO.

WAILES DOVE-HERMISTON CORP.—Bituminous protective coatings and bituminous paints. In charge of exhibit: Willard T. Chevalier.

WALLACE & TIERNAN CO., INC.—Special chlorine control apparatus for use in bleaching paper and textiles, deodorizing, oxidizing and other chemical purposes; chlorine control apparatus for sterilizing water supply, sanitation of swimming pools and disinfection of sewage; valves, gages and flow meters for handling corrosive materials. In charge of exhibit: M. F. Tiernan, Wm. J. Orchard, L. H. Goebel, R. V. Donnelly and H. D. Thompson.

WARNER CHEMICAL CO—Nelson electrolytic cell. In charge of exhibit: William B. Thom, John A. Chew and S. C. Mastick.

WERNER & PFLEIDERER—Kneading and mixing machines adapted to the chemical industry; laboratory-size mixers in operation; large-size steam jacketed machine; photographs of large installations. In charge of exhibit: A. J. Vollrath, J. C. Caley, S. D. Gridley and Miss E. Ziegler.

WESTINGHOUSE, CHURCH, KERR, INC.

WESTINGHOUSE ELECTRIC & MFG. CO.—A.c. and d.c. specially impregnated motors, arc furnace regulating and control panels, industrial heating appliances, starting switches, control switches, etc. In charge of exhibit: C. B. Gibson, C. G. Schluederberg and G. H. Jaspert.

WHEELER, C. H., MFG. CO.—Radojet air pump model, showing the inside; single and double stage radojet air pumps; duplex condensate pump; automatic steam pressure and temperature regulators. In charge of exhibit: G. L. Korthing and Charles Lang.

WHITALL TATUM CO.—Nonsol chemical glassware. In charge of exhibit: W. W. Figgis.

WHITLOCK COIL PIPE CO.—Special apparatus for heating water for use in chemical and industrial plants; coils of iron and steel pipe and copper tubing for use in chemical processes. In charge of exhibit: W. H. Ripley, E. B. Cole, S. T. Green, W. A. Evans and C. I. Babcock.

WIDNEY TEST LABS.

WILLSON GOGGLES, INC.

WOLF, JACQUES, & CO.—Sulphonated oils, softeners and finishing preparations; specialties for the textile trade; hydrosulphites. In charge of exhibit: Alfred Pfister, and Messrs. Deuble, Goss, Henckel, McDonagh, Griffith, Royce and Desmond.

WORTHINGTON PUMP & MACHINERY CORP.

ZAPON LEATHER CLOTH CO.

ZAREMBA CO—Large-size photographs illustrating characteristic Zaremba evaporator installations. In charge of exhibit: H. E. Jacoby and W. H. Eggert.

Chemical Problems of the Beet Sugar Industry

Attainment of Greater Yields of Sucrose by Better Beet Culture and Improved Refining Processes Possible—Byproducts From Molasses: Potassium Carbonate and Sulphate, Methylamines, Cyanides, Methyl Alcohol, Ammonia and Bleaching Carbon

BY H. W. DAHLBERG*

THE chemical and chemical engineering problems in connection with the manufacture of beet sugar are many and varied in character. The extraction of sugar from the sugar beet involves the separation of sucrose from the organic and inorganic impurities with which it occurs in the beet. Since these impurities include all the soluble salts of the soil as well as a large number of vegetable acids and their salts formed during the growth of the beet, the process of sugar manufacture consists of the necessary steps to eliminate these non-sugars and obtain sucrose, $C_{12}H_{22}O_{11}$, in a pure form.

The average sugar beet has the following approximate composition:

	Per Cent		Per Cent
Sugar	16.00	Ash	0.80 to 1.00
Water	77.00	Organic non-sugars	1.50 to 1.50
Marc	5.00		

The sugar content and purity of the beet varies considerably with the soil and with climatic conditions. By "purity" we mean the percentage of sugar contained in the total dry substance of the juice from the beet. The purity may vary from 80 to 88 per cent and the sugar content from 11 to 20 per cent or even higher. Beets of the highest sugar content and purity are, of course, the most desirable, as the yield of sugar obtained from such beets is high. A great deal of study has therefore been given to developing strains of beet seed which will produce beets of the desired quality. The fact that the present sugar beet containing 16 to 20 per cent sugar has been developed by breeding and selection from a small, wild beet containing practically no sugar indicates the progress that has been made.

*Research Manager, Great Western Sugar Co.

The process by which sugar is obtained from sugar beets is briefly as follows: The beets are washed, weighed, and sliced, and the slices are treated with hot water in a series of tanks called a diffusion battery. During successive washings the sugar contained in the cells of the beet diffuses through the cell walls and is dissolved in the water, forming "diffusion juice," which is a dilute sugar solution of about 85 purity and containing about 12 per cent sugar. The diffusion juice is purified by successive treatments with lime, carbon dioxide and sulphur dioxide, filtered, evaporated to a sirup and then boiled until sugar crystallizes out. The final products obtained are pure granulated sugar and the byproduct molasses. The latter will be discussed more fully below.

The mineral salts present in the beet are very largely soda and potash, combined with organic and inorganic acids. As they are very soluble and are carried on through the process without much elimination, they are the most harmful of all the impurities. Each part of mineral non-sugar carries with it from 1½ to 3 parts of sugar into the molasses, a byproduct from which no more sugar can be crystallized due to the concentration of impurities. For this reason it is highly desirable to grow the beets in soils and under such fertilizing conditions that a minimum of mineral salts is contained in the beet.

As an example, sugar beets grown in Germany contain approximately one-half as much ash as those grown in the United States, due to soil less rich in soluble salts and a more careful application and control of fertilizers. The result is that the yield of sugar is higher and the amount of molasses produced is much less than in our practice. It must be recog-

nized, of course, that potash and other salts are absolutely essential for the growth of the sugar beet, so that it must always contain an appreciable quantity of mineral impurities.

Mineral Content of Beets, Diffusion Juice and Molasses

The following table shows the analysis of the ash from typical samples of beets and the diffusion juice and molasses produced from them. It should be borne in mind that in making the ash determination the salts of organic acids are broken up and the bases converted into carbonates. As the weight of the carbonates is considerably less than that of the organic salts from which they are derived, the ash content is always less than the actual content of salts.

	Beets	Diffusion Juice	Molasses
Per cent lixiviated ash by weight	0.85	0.53	11.80
Analysis of ash:			
Silica and insoluble	2.64	2.00	.86
Iron (Fe)	1.84	.22	.11
Calcium (Ca)	.59	.44	.51
Magnesium (Mg)	2.05	3.39	.34
Potassium (K)	30.55	31.44	40.40
Sodium (Na)	11.28	11.05	8.68
Chlorine (Cl)	6.87	7.71	9.76
Sulphate (SO_4)	3.61	5.92	10.74
Phosphate (PO_4)	7.42	7.54	.40
Carbonate (CO_3)	30.98	30.43	28.74
Undetermined	2.17	.....	.....
Total	100.00	100.14	100.54

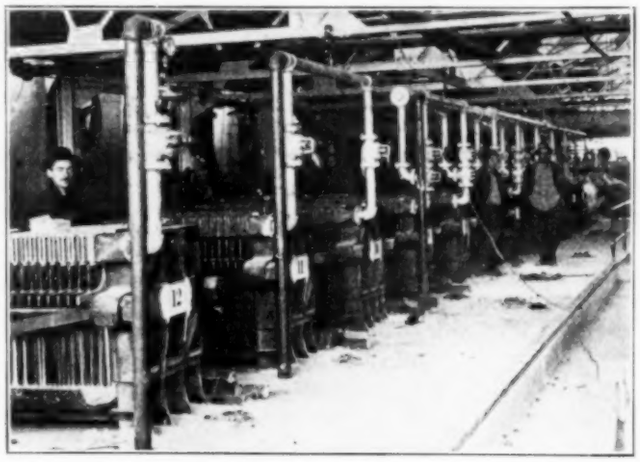
With proper operation of the diffusion battery, from 20 to 30 per cent of the total ash in the beets is eliminated at this stage. As will be seen from the above analysis, the composition of the ash remains about the same in the juice as in the beets. Minor differences are caused by the mineral solids in the supply water. In securing high extraction it is, of course, just as important to have the purest obtainable supply water as it is to have beets low in mineral salts. It has been found that the loss of sugar in molasses is almost directly proportional to the amount of ash in the diffusion juice, indicating that the mineral non-sugars are much more melassigenic than are the organic non-sugars.

FACTORY INTERIOR: DIFFUSION BATTERY IN FOREGROUND

The problem of a more complete separation of the sugar from the impurities in the beets is one which has received a great deal of study ever since the industry began, but still remains to a certain extent unsolved. If a cheap process of precipitating the sugar in an insoluble form, leaving the non-sugars in solution or vice versa, could be found, the yield of sugar in the form of granulated would be increased about 15 per cent, and the loss in molasses correspondingly reduced.

Molasses

The method of attack on this problem has been to allow the impurities and sugar to accumulate and be concentrated in the form of molasses, a material which contains 50 per cent sugar and 30 per cent non-sugars.



FILTER PRESS STATION

The sugar is then precipitated from the molasses as saccharates and finally obtained as granulated.

Molasses is a byproduct of beet sugar manufacture which offers very interesting possibilities for research work and the production of many further byproducts. As shown by the analysis given below, it is a mixture of a great many chemical compounds. The multiplicity of these has tremendously increased the difficulties of research work on this material, but considerable progress is being made. I might mention that under "Undetermined" may be included as many as twenty different organic non-sugars, gums, etc.

COMPOSITION OF BEET MOLASSES

Moisture	21.00	Invert sugar	0.06
Direct polarization	52.08	Ash	12.17
Sugar by inversion	50.51	Undetermined	15.41
Raffinose	0.85		

As mentioned above, although the molasses contains 50 per cent sugar, the non-sugars present absolutely prevent its crystallization, so no more sugar can be obtained by simple evaporation. Consequently it becomes necessary to use a precipitation process, such as the Steffens process, whereby the sugar is precipitated as tricalcium saccharate, and filtered from the mother liquor, called waste water. The Steffens process consists of dilution of the molasses, adding to the 5 per cent sugar solution finely powdered lime at a low temperature and with rapid agitation, until nearly all of the sugar is precipitated. The saccharate is filtered, washed and carbonated to liberate the sugar, finally giving a juice of about 90 purity, from which granulated sugar can be obtained.

One of the serious objections to this process is the relatively low purity of the saccharate produced, causing a reintroduction of impurities into the process. These impurities consist of a number of organic compounds which are precipitated by lime the same as sugar, and accumulate in the final molasses to such an extent that the yield of sugar from the Steffens process becomes too small to be profitable. When this occurs it becomes necessary to discard all of the molasses in process in the sugar factory and thus eliminate the objectionable impurities. The impurity which causes the most difficulty is the so-called "raffinose," as determined by the Clerget inversion method. This so-called "raffinose" is evidently in part true raffinose, and in part consists of other optically active compounds which have not been isolated and identified. Wherever the term "raffinose" is used in this paper it represents this unknown compound or mixture of compounds and not true raffinose.

Raffinose

Several peculiarities have been noticed regarding the accumulation of "raffinose." One of these is that the calcium saccharate produced from molasses containing "raffinose" almost invariably shows an increase in raffinose, the total quantity present being 20 to 40 per cent greater than in the molasses itself. As yet no satisfactory explanation of this increase has been found. Another peculiarity is the fact that in climates where the beets are not exposed to freezing temperatures, as in California, no raffinose accumulates in the molasses, eliminating the necessity for discarding. Factories in localities with low temperatures during the manufacturing season, such as Colorado, Utah and Michigan, using the Steffens process, find it advisable to discard 25 to 40 per cent of the tonnage of molasses worked by this process. An analysis of discard molasses shows the accumulation therein of raffinose and organic compounds, the latter listed as "undetermined."

DISCARD MOLASSES

Moisture	20.13	Invert sugar	0.00
Direct polarization	56.90	Ash	11.87
Sugar by inversion	49.02	Undetermined	14.78
Raffinose	4.20		

There are two processes which may be used for the recovery of sugar from discard molasses—i.e., strontium or barium oxide form saccharates of higher purity than does lime. Several sugar companies are now experimenting with these two processes. The principal difficulty to overcome is the high cost of converting strontium or barium carbonates back to the oxide, as is necessary because of the original cost of these reagents. The conversion has been made in electric furnaces with some success, but at an excessive cost. The strontium process has been used extensively in Germany for many years, but has not yet been made a commercial process in this country. Both processes have the advantage over the Steffens process of producing a concentrated waste water which can be worked up for potash and other byproducts at less cost.

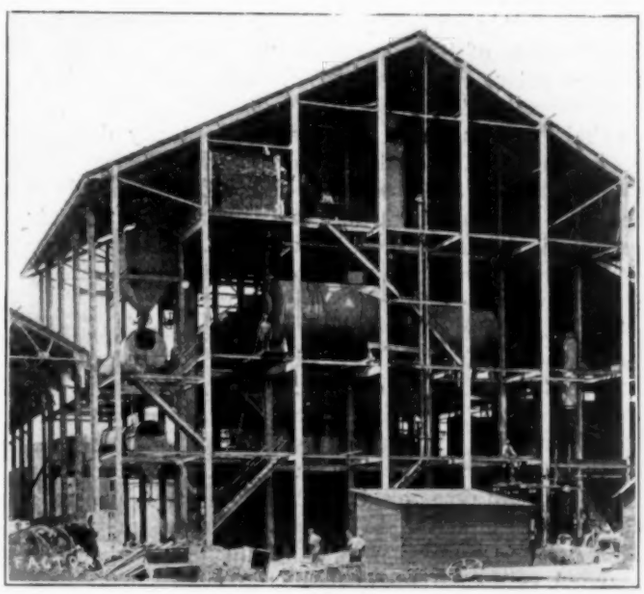
Byproducts From Molasses

The ash in molasses contains nearly 50 per cent of potash as K_2O and therefore is a valuable source for this material. Before the war this potash was not recovered by the sugar companies of the United States, it being impossible to compete with the price of potash imported from Germany. During the last three or four years, however, large installations have been made to recover potash from beet molasses, and the recovery is being done very successfully. The Great Western Sugar Co. of Colorado now produces about 6,500 tons of ash of 40 per cent K_2O content annually. This is done by evaporating the waste water from the Steffens process in multiple-effect evaporators, burning the thick liquor in special furnaces, leaving the ash as residue. This material is now sold for fertilizer use, but may ultimately be refined and part of the potash secured as potassium carbonate, a more valuable product. In the process of refining, a considerable quantity of vegetable carbon is obtained, which may be utilized for the decolorizing of sugar solutions.

By the present process of burning the waste water liquor, nearly all of the nitrogen contained therein is lost. As the original molasses contains 1.5 to 2.0 per cent total nitrogen, most of which stays in the waste water, the recovery of the nitrogenous compounds offers great possibilities. Progress is now being made in the recovery of methylamines, cyanide and ammonia from this waste liquor. This will be done by destructive distillation, absorption and purification of the gaseous products.

A large portion of the nitrogen in molasses occurs in the form of betaine or trimethyl-glycocol, $C_5H_{11}NO_2$. This can be obtained in considerable quantities from beet molasses as beautiful crystals of betaine hydrochloride, a compound which is used to some extent medicinally for treatment of digestive disturbances.

On subjecting the betaine and other nitrogenous compounds to destructive distillation, a mixture of mono-, di- and tri-methylamines with ammonia is formed. Di-methylamine is a valuable raw material in the dye industry, and some of the addition products of the amines are attracting attention as accelerators in vulcanizing automobile tires. Constant research work is being carried on to determine the best methods to secure high yields and purities of the above-mentioned products from molasses. This is necessarily a slow process, involving, as it does, research in pure chemistry and the solution of the chemical engineering problems



SUGAR FACTORY UNDER CONSTRUCTION, SHOWING VACUUM PANS, CRYSTALLIZERS AND CENTRIFUGALS

encountered in developing the commercial process from the methods found successful in the laboratory. Some of the products are being made from molasses waste liquor in Germany, but very little information as to methods is available. It is also to be remembered that processes using excessive manual labor might be commercially successful abroad and fail in this country because of high labor costs. Consequently it is desirable to develop processes which are as nearly mechanical and automatic as possible.

Future Research Work

I will suggest several lines of research work to complete our present knowledge and develop a well-rounded process for the utilization of molasses. Such a process would yield the following known products, and it is possible that many others would ultimately be obtained:

Sugar	Methylamines
Potassium carbonate	Sodium cyanide
Potassium sulphate	Ammonium sulphate
Sodium carbonate	Methyl alcohol
Vegetable carbon	Vegetable tar

The individual steps in this process would be: 1. Recovery of sugar as strontium or barium saccharate. 2. Distillation of concentrated waste water. 3. Recovery and separation of methylamines, sodium cyanide, ammonium sulphate, methyl alcohol and tar as products of distillation. 4. Refining of crude still residue for the potash and sodium salts.

Still further products can doubtless be obtained by the distillation of the tar. The vegetable carbon may be used as a decolorizing medium or in the manufacture of shoe blacking.

Another line of work which has been suggested is the decomposition of waste water by electrolysis, which might yield caustic potash and valuable organic acids. With the advances which have been made in electrolytic cells and electrochemical processes during recent years, this line of attack offers attractive possibilities.

In the event that the extraction of sugar from molasses is not sufficiently profitable, a substitute process would be the production of yeast, alcohol or acetic acid. This is, of course, a commercial process now.

A highly desirable research work that should be taken up as soon as possible is the isolation and identification of the so-called "raffinose" and other optically active compounds. This will involve methods for the exact determination of each, and also methods for their removal from molasses without any destruction of sugar. I wish to emphasize that this problem is no mean task, and that some of the keenest minds in the sugar industry, both here and abroad, have already spent years in doing the pioneer work. Although the results of this work have been of great value, scarcely more than a beginning has been made.

A chemical engineering problem which deserves attention is the burning and grinding of lime under such conditions that it will give the maximum results in the Steffens process. A study of the values of various limes shows that the physical characteristics of any lime are almost as important as its chemical purity. For this reason two limes produced from the same lime rock and chemically active to the same extent may give rather widely different results in the precipitation of sugar. A very desirable quality in lime for the Steffens process is that it shall be light and fluffy in character.

The filtration and washing of the large quantities of calcium carbonate and saccharate produced in beet sugar factories is worthy of more study. Although gratifying progress has been made during the last ten years, the industry is still in need of filtering apparatus which will give minimum sugar losses with low costs for labor, filtering media and evaporation of wash waters.

A byproduct of interest to the chemist is beet pulp, the residual beet slices after the sugar has been extracted. This material has considerable food value and is fed in either a wet, fermented state, or as a dry material. During fermentation of the wet material a very large loss of food value takes place, and the time may come when the chemist will develop uses for pulp which will utilize all of the values contained to a greater extent than is now being done.

In this discussion I have attempted to cover in a general way the lines along which scientific research and development is needed in the beet sugar industry, without going into any exhaustive treatment of the problems which we have to meet. It is perhaps not too much to say that in dealing with the byproducts of the sugar beet "only the surface has been scratched." Any success that the scientific men of the industry may attain in this direction will come with frank and open discussion and interchange of ideas and elimination of the secrecy which has hampered the development of so many chemical processes.

Denver, Col.

Chemical Control in the Sugar Industry

In the Aug. 7, 1920, issue of *The Louisiana Planter* S. J. Osborn, of the Great Western Sugar Co., writing on "The Chemical Control of the Sugar Industry," states that: While the sugar manufacturing process is not a highly complicated one, as chemical processes go, it is doubtful if any other manufacturing process is so closely and thoroughly controlled at every step by the chemical laboratory. The laboratory is called on for information and advice in solving the numerous technical problems which arise, and its assistance can be of the greatest value. One of the problems of the chemical department is the question of the extent to which work that does not have an immediate application shall be carried out.

In companies of sufficient size the chemical control work is handled by a specially organized chemical department entirely independent of the operating department, although the two naturally enjoy intimate relations and must work in close co-operation to achieve the best results. This system has many advantages. Not only does it relieve the operating department of responsibility for a highly technical line of work, but it puts the results on a basis where they are free from even any suspicion of bias or irregularity, and facilitates the introduction and use of uniform methods in analysis and control.

An important factor in the development and application of chemical control in all branches of the sugar industry is the extent to which rapid and reliable control methods have been worked out.

The chemical department of a sugar plant usually has a wider field than that its name might imply. It issues and is responsible for almost all of the important operating reports, other than the financial, and keeps a detailed set of records with the help of which the operating efficiency of the plant might be improved.

The Problems of the Petroleum Industry

Greater Supplies of Crude Oil Required to Meet Future Demands—Better Utilization of Supplies Necessary—Pyrolysis of Fuel Oils Into Gasoline—Substitutes for Petroleum Products—Chemical Synthetic Products From Petroleum

By WILLIAM A. HAMOR*

BENJAMIN SILLIMAN, JR., who conducted the first technochemical investigation of crude petroleum, in 1855, remarked that it was a raw material from which might be manufactured very valuable products. With an industrial history covering a period of but sixty years, crude petroleum now is recognized as a resource of the highest economic value to society because it is essential to agriculture, manufacturing, commerce and the pleasures of life. It is the source of gasoline, which is responsible for the development of the internal-combustion engine, the increase of the use of which has strengthened the entire aspect of modern civilization; it gives the world its supply of illuminating oils, which, by bringing a cheap light to millions of people, have constituted America's greatest gift to the uncultured peoples of the globe; and it provides the lubricating oils upon which the complex mechanical equipment of today is dependent for its operation. Then, too, part of the industrial activity of our country rests upon another petroleum product, fuel oil, which also is required for the operations of an oil-burning navy.[1] The fact that crude petroleum forms the basis for a chemical products industry of almost unlimited possibilities of development, and as distinctive as the coal-tar industry of the present, brings out, in addition, its predominant importance among mineral raw materials.

A substitute has been found for crude petroleum, but shale oil, to which reference is had, is a chemical product and therefore is subject to economic limitations not applicable to a substance which may be mined and handled so easily as crude petroleum. Indeed, the availability and magnitude of the petroleum resource have given confidence for the extensive mechanical developments essential to its use; and accordingly the employment of petroleum is established among the practices and requirements of modern life. As pointed out by Gilbert and Pogue,[2]

> Any tendency toward disuse of its essential products, either through undue increase in price or from decline in production, will mark a turning point in material comfort and industrial advantage, the deferring of which becomes an object of universal concern. As the petroleum deposits of the United States have been drawn upon with extraordinary rapidity and the supplies have already suffered serious depletion, the matter of their approaching exhaustion assumes the light of immediate importance. The comforting assertion that such considerations may be safely left to future generations does not apply to petroleum.

Crude petroleum now is being taken from the ground in the United States at a rate approaching 400,000,000 bbl. per annum. This is five times the rate in 1901 and twice that of 1909.[3] At the close of 1919 approximately 4,986,300,000 bbl. of crude oil had been produced in this country since the first well was drilled at Titusville, Pa., in 1859. This is about 43 per cent of the original recoverable content, as estimated by the United States Geological Survey. All this oil that has been mined in the United States in sixty years would be taken out in thirteen years at the present rate of production. Impressive as this fact may be, it is not so disturbing as the realization that the recoverable crude petroleum in this country, according to the conservative estimate, would probably be practically exhausted in seventeen years if the 1919 rate (nearly 380,000,000 bbl.) of production could be maintained for so long, while a reserve of 7,000,000,000 bbl., the moderately liberal estimate, would disappear in eighteen and one-half years.[4] If an improbable excess of 2,500,000,000 bbl. over the estimated amount is present, this excess would be sufficient to sustain the present draft for six and one-half years additional.

What improvements will in the next ten years be made in the process of extraction of crude oil from the ground, and what the effects may be in recovering the great amounts of crude petroleum not "available" or recoverable by present methods, remains to be seen. It is probable that not much over 20 per cent of the oil underground is brought to the surface. It is most important that studious attention be given to the problem of the more complete extraction of the petroleum than is possible by the methods now in general use. Records of wells should be kept, surface and underground geology should be correlated, oil-sand should be examined, and if possible underground losses should be determined. The estimated available supply should be increased in this way to the maximum. It is noteworthy that while the petroleum industry has been supplied with technical means whereby certain wastes in production may be combated there has been provided no adequate machinery for applying this knowledge.

Fortunately, however, the crude petroleum cannot so soon be taken from the ground. Even unparalleled prices for crude oil, and exploratory work far more extensive than that now in progress, cannot within the next generation disclose all the oil pools in the strata; and although devices for more rapid extraction may be invented and applied, the fields which remain to be discovered cannot be drained so rapidly. Oil pools will be found, finally by accident, long after the search has waned, and even in the next century. These are some of the reasons why the production of natural petroleum in the United States must pass its peak at an early date—probably within five years and possibly within

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[1] Forty-eight per cent of the power used by the British Navy in the European war was derived from petroleum and the fleet steamed 7,000,000 miles per month. In 1918, 3,000,000 tons of fuel oil were shipped from the United States to the Allied navies. U. S. National Museum, Bulletin 102, I, ii, p. 29.

[2] See "World's Production of Petroleum," U. S. Geological Survey, Jan. 22, 1920.

[3] Dr. David White, of the United States Geological Survey, has furnished these data.

three years—while the long sagging production curve may be carried out beyond the century. It is certain that this country must in the near future lose its supremacy in the petroleum world and become more and more dependent on the oil resources of other lands,[5] except in so far as the situation may be saved by the successful production of artificial petroleum (crude shale oil) by the destructive distillation of American oil-shales.

To depend on oil-shale, however, is to trust to uncertainties both as to costs and as to ultimate results, and is at best to superimpose on our present social and industrial fabric an enormous and complex new industry rivaling in part our coal-mining, salvaging but a part of our present petroleum industry, and requiring many years for its development. Sooner or later—perhaps within five years—a commercial shale-oil industry may be born in this country, but that it can originate soon enough or become large enough to offer any considerable contribution before our domestic petroleum production is already on the wane seems improbable. Finally, if shale oil yielding the principal and indispensable petroleum products cannot successfully be produced and marketed as cheaply as natural petroleum

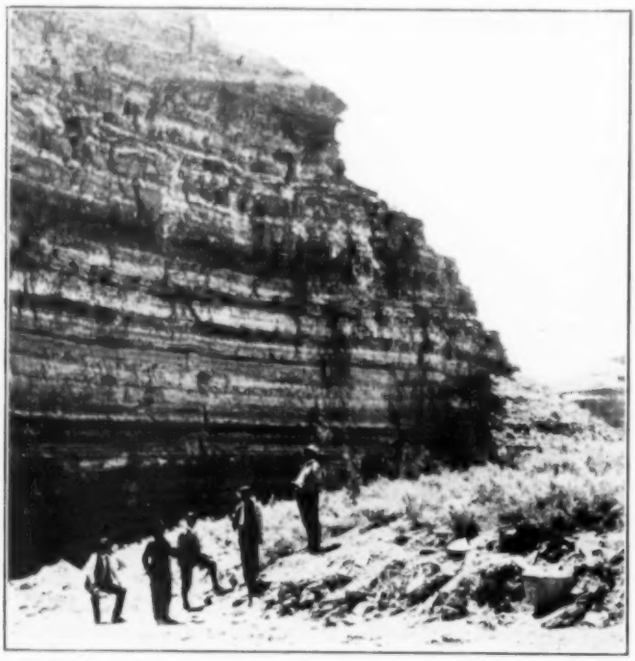

FIG. 1. OIL SHALE ON WILLOW CREEK, SOUTHWESTERN UINTA COUNTY, UTAH

from other countries, the public cannot be expected to build up and sustain a shale-oil industry, unless it be under subsidy as a protective measure.

To date approximately 140 shale-oil companies, many of which claim to own or control novel distillation processes, have been formed in the Western oil-shale fields; but so far none of these organizations has assumed a position of commercial importance. However, research of a fundamental character is being carried out by various large petroleum interests and by the Bureau of Mines. It is hoped that the Bureau of Mines will serve the useful function of investigating new types of retorts and of determining the most profitable use and method of treatment of any particular oil-shale. This valuable pioneering work would bear fruit ultimately in the production of a notable volume of shale oil.

A British oil economist has calculated that by 1925 the petroleum requirements of the United States will exceed 500,000,000 bbl. and that at a later date our country will become more and more dependent upon British supplies. An American authority, W. C. Teagle, president of the Standard Oil Co. of New Jersey, has estimated that in 1925 the requirements of the petroleum industry in this country will approximate 650,000,000 bbl., an increase of more than 220,000,000 bbl. over the requirements of 1919. Unless conservation of petroleum through curtailment of use—for example, as fuel burned under steam boilers to generate steam—is forced automatically by the scarcity of crude oil and consequent prohibitive prices, or is sooner and more wisely brought about artificially by regulation, it seems probable that the demands of the American petroleum industry will considerably exceed 600,000,000 bbl. or possibly 650,000,000, as estimated by Teagle, in 1925, although by that time our exportation of refined oils to some of the foreign markets will probably be reduced by the competition of foreign oils nearer at hand and more cheaply produced.

A drain of over 500,000 bbl., even if the yearly effectual demand be not further increased, would, if taken from the oil fields of the United States, probably exhaust the petroleum resources remaining available in the ground in fourteen years, or in sixteen years if it is assumed that the recoverable petroleum possibly amounts to so much as 8,000,000,000 bbl., which seems very improbable to geologists. It is fortunate for the country that the petroleum cannot be extracted so rapidly. On the other hand, it also seems quite improbable than an annual production of natural petroleum amounting to so much as 450,000,000 bbl. can be won in any year from our domestic oil fields, the peak of whose production is likely to be passed by 1925.

All circumstances being considered, it must be expected therefore that, unless our consumption is checked, by 1925 the United States will be dependent on foreign oil fields to the extent of 150,000,000 bbl., and possibly as much as 200,000,000, of crude oil each year, except in so far as the situation may by that time, perhaps, be helped to a slight extent by shale-oil. Add to this probability the other greater probability that within five years—perhaps three years only—our domestic production will begin to fall off, with increasing rapidity, due to the exhaustion of our reserves, and it becomes evident that, except for such relief as may come from shale-oil production, the future of the United States in petroleum will yearly become more and more completely dependent on supplies to be brought from foreign fields.[6]

As the outlook now must be viewed, it is practically certain that after a time the United States will be buying petroleum from commercial rivals in quantities greater by far than ever have been sold to them, to make no mention of the prices paid. But, while this may be impreventable, it should be escaped as far as

[5] On the restrictions imposed by certain foreign countries upon citizens of the United States in prospecting for or acquiring lands containing petroleum, see Senate Document 272, May 17, 1920.

[6] United States interests are practically supreme in the commercial control of the petroleum resources of the Western Hemisphere, dominating the petroleum industry in the United States, Canada, Mexico and Peru, and holding substantial interests in Trinidad and Venezuela and in the prospective petroliferous areas in Central America and Colombia. Their only competitors are British and British-Dutch interests, which control the petroleum situation in Trinidad and are not only strongly intrenched in Mexico and Venezuela but are aggressively seeking to enlarge their holdings in those countries and to gain footholds elsewhere.

possible. If our nation is to have these oils as cheaply as they are sold in the home countries; if our industries, our transportation, our navy and our standards of living are to be safeguarded in advantages as great as those of our rivals, and if our merchant ships are to obtain their fuel oil at prices as low as those paid by rival ships, the oil supplies needed must be in our control. Our prosperity and our prospects, so far as they may be affected by this important commodity which influences the daily life of every citizen, must not be subject to prejudicial regulation or discriminative restriction by any foreign power. Only by assuring American control over the petroleum supplies required by the United States can the protection of our future be guaranteed.

Experts believe that the most conspicuous developments affecting the sources of the world's supply of petroleum in the next decade will occur in the countries that border the Caribbean Sea and the Gulf of Mexico. Within the last four years the annual production of petroleum in Mexico has increased from 21,000,000 bbl. to 56,000,000 bbl.[7] and the potentialities of future production in that country have been demonstrated. It is estimated by T. C. Thomson[8] that the ultimate expected production will equal, if not surpass, the whole production of the United States. Its product, originally considered valuable only as a source of fuel oil, now is yielding, by modern refining methods, increasingly important percentages of illuminating oils and gasoline. The hindrances to enormously increased production are unsettled political conditions and inadequate facilities for marine transportation, but these obstacles doubtless will be surmounted within the next few years.

To summarize, the future domestic supply of crude petroleum will not be equal to the future home demands. This problem can be met by:

(1) Obtaining greater supplies of crude oil—
  (a) By increasing the importations from foreign oil fields.
  (b) By actively participating in the development of foreign oil fields.
  (c) By the establishment of a shale-oil industry on a commercial basis as soon as is practicable.
  (d) Through increased recovery from our oil fields, resulting from more efficient operating methods, and especially the elimination of wastes in production.

(2) A better utilization of the crude now available, principally—
  (a) By the pyrolysis of fuel oils into gasoline.
  (b) By the development of gasoline substitutes.
  (c) Through the development and use of Diesel-type engines utilizing the heavier fuel oils.

Problems in the Production of Crude Petroleum

Among the development and production problems which require more study are the dehydration of emulsified petroleum and the prevention of its formation in oil wells. It has been learned that probably all emulsions in wells are formed after the oil has left the sand, and their formation often can be prevented. The systematic investigation of methods for excluding water from oil and gas wells, of the effect of water on the production of oil wells, and of casing and tubing problems, would lead to findings of technical value. Work on the employment of safety devices in the oil fields, the possible substitution of explosives safer than nitroglycerine for shooting oil wells, and the effects of shooting on wells, would be of utility. Scientific inquiries for determining the capacities and characteristics of oil and gas sands, the proportions of petroleum not being recovered by present methods of production, and the laws governing the expulsion of petroleum from the oil sands have been started by our energetic Bureau of Mines. There is little information on this subject, and it will not be possible to interpret data and to judge the value of various methods of production until the underlying geochemical laws are better understood. Procedures for stimulating production and increasing the recoveries of petroleum from the sands, including the effects of vacuum pumping, use of compressed air or gas, and use of water flooding, present other opportunities for research. In this connection, pumping problems and equipment, including the use of automatic air and gas pumps, electrical equipment, and air lifts should be given attention.

Storage and transportation problems include losses of oil in storage, prevention of fires at tanks and wells,[9] the flow of oils in pipe lines, and the construction of storage tanks and reservoirs.

Some Problems in Refinery Technology

Petroleum industrialists frequently have availed themselves of the service of scientific research[10] both in the development of processes and in the perfecting of the necessary mechanical equipment. In fact, marked success has attended scientific progress in the refining of petroleum, and the largest refineries now concede that chemistry is the source of specific information for the petroleum industry and gratefully acknowledge that the efficiency of their plants has resulted largely from properly conducted scientific investigation. Those companies which stand well to the fore maintain one or more research laboratories, and industrial research has left its mark on their development. It is, however, essential, particularly for the future welfare of the industry, that there be an increment in investigational activity. This may be brought about in a measure by the organizations represented in the petroleum industry, especially the American Petroleum Institute, and by the Bureau of Mines; but there must be more cooperation between petroleum industrialists and the universities and scientific societies if the desirable fruitful research is to be stimulated.

The need of continuous study and research and training in hydrocarbon chemistry and in petroleum technology cannot be over-emphasized.[11] The lack of reliable general information has worked handicaps on the petroleum industry, which is, in many ways, groping in the dark. Similar errors are made repeatedly in the same territory by different operators, and both in

[7] In the same period our imports of Mexican crude petroleum have increased from 15,175,061 bbl. to 45,893,945 bbl.

[8] *J. Inst. Pet. Tech.*, vol. 5, p. 56.

[9] On oil fire hazards, see Bulletin 170, Bureau of Mines.

[10] A good illustration of what research has done in working out refining problems is had in the case of liquid petrolatum. At the beginning of the war a great shortage of this product occurred, since its manufacture had been carried on solely by the Germans from Russian petroleum stock, which was thought to be the only suitable basis. After scientific inquiry the manufacture of liquid petrolatum was begun on American oils, and the present American product is superior to the old German "paraffinum liquidum" in a number of respects.

[11] It is gratifying to note, however, that at least one American institution now is supplying trained petroleum chemists to the industry. Reference is had to the University of Oklahoma, where Prof. F. W. Padgett is giving systematic instruction in hydrocarbon chemistry and refinery technology.

drilling and in refining the various factors having a known influence are understood imperfectly in their relation one to another. Geology, the real foundation of a study of production, is insufficiently applied or understood by the average producer, and in consequence much of the production is accidental rather than scientific. When a producer finds petroleum he is simply a producer, and not a marketer, for he has usually no knowledge of the value of his product other than the posted price. He knows only in a rather vague

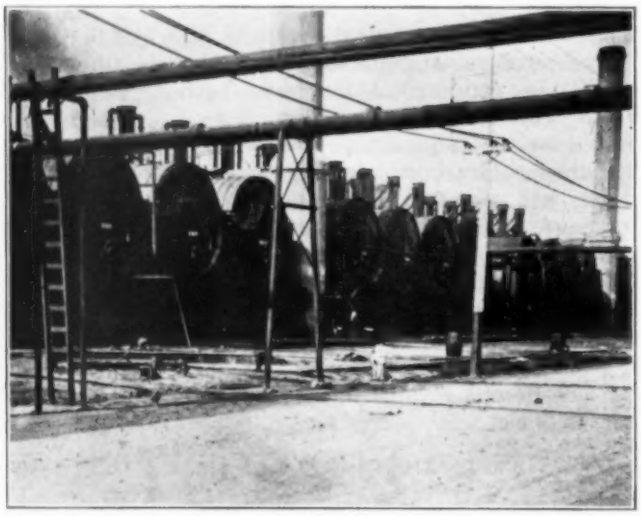

FIG. 2. A BATTERY OF 1,200-BBL. CRUDE OIL STILLS OF THE LATEST DESIGN

way what characteristics are valuable; and when he has sold his crude oil he frequently is concerned no longer with the petroleum industry. The refiner usually has only the knowledge gained by an apprenticeship with an older refiner, and is therefore nescient regarding the chemistry of refining.

Petroleum marketers consider that the greatest need of those engaged in the petroleum industry today is uniformity in methods of testing and in the physical instruments employed therein. Constant progress is being made in the analytical chemistry of petroleum and its products, but much research will be necessary before precise and detailed procedures are worked out which will be satisfactory for general adoption. It is not practicable to issue standard test samples, as is the case for the iron and steel industry, but there can be laid down definite, standard instructions for carrying out the various operations involved.

A large literature already exists on the subject of analytical naphthology owing to the activities, among others, of the Bureau of Mines and the Bureau of Standards in the United States and of the National Physical Laboratory in England. What is needed now is the welding of these researches into a comprehensive whole by an international body of experts, which, sitting permanently like the pre-war International Petroleum Commission, shall institute researches into new methods of procedure and revise existing technic.

From the industrialist's viewpoint, the great problem in the petroleum industry is flexibilty in refining, in order that there may be produced only those products which are in demand. In other words, there is wanted a suitable process which will enable the refiner to manufacture only the products for which there is a big market—say gasoline and lubricating oils. Research has been begun which has for its object the production of the desired finished oils, and only these, by purely physical methods, thus dispensing with chemical treatment.

Considerable investigation has been devoted to working out processes for the dehydration and desulphurization of crude oils and for the pyrolysis of heavy oils (particularly the conversion of such oils into motor fuel). Findings of importance have resulted from these investigations, but the ideal processes remain to be found, especially methods for converting products of the destructive distillation of residuum or heavy oils into saturated hydrocarbons. If hydrogenation could be conducted successfully on a commercial scale the customary treatment with sulphuric acid could be dispensed with. Hydrogenation with platinum black or nickel could be accomplished if an antidote were known for the poisonous effect of sulphur compounds on the catalyst. Another matter of interest here is the polymerization of olefines; this subject requires the consideration of research.

Automotive engineers should have available exhaustive data regarding the specification and use of petroleum products for internal combustion and lubrication purposes. Lubricating oils for special purposes have not received due scientific attention, and, as a result, the selection of a lubricant is more frequently casual than scientific. Lubrication is a special problem of colloid physics.[12]

It is singular that the subject of refining has attracted so little notice. In the chemical treatment of petroleum products systematic investigation, with the object of ascertaining the most favorable temperatures for the acid treatments of petroleum distillates, would be of practical value as affording an indication to the refiner how to proceed under all circumstances. Another well-known problem in refining is the chemical treatment of lubricating oils in such manner as to minimize the losses and to prevent the emulsions which result when sulphuric acid is used. The production of persistent emulsions in the refining of petroleum is a problem to be attacked from the colloid-chemical point of view. An economic process is needed for isolating pure naphthenic acids of high molecular weight from

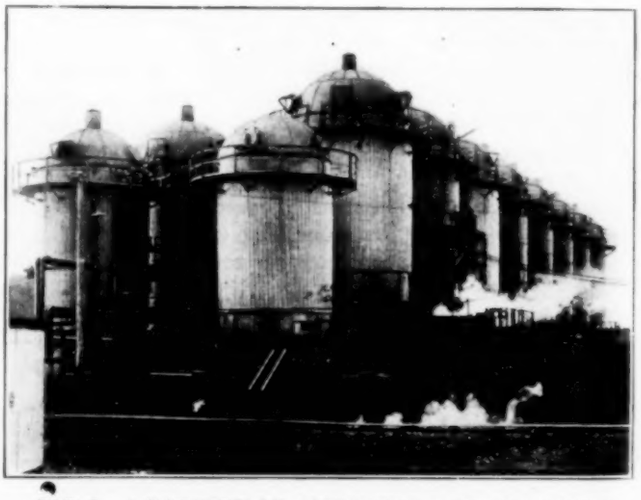

FIG. 3. A BATTERY OF AGITATORS, EACH OF ABOUT 1,200-BBL. CAPACITY

[12]In fact, W. B. Hardy (*J. Soc. Chem. Ind.*, vol. 38, 1919, p. 77) has shown that we may look with confidence to colloid chemistry to assist us in finding the lubricants of the future.

waste lyes. A related problem is the utilization of the esters from the naphthene carbo-acids contained in the residue from the alkali treatment. A question of interest here is: What is the cause of the cacodor of naphthenic acids, and how may these products be deodorized most effectively and economically?

The following are some of the many other problems confronting petroleum technologists: A more rational utilization of the butanes and pentanes in natural gas gasoline and in light petroleum fractions; does the hot still metal exert any catalytic action in the pyrolytic decomposition of residues; the minimization of the decomposition of sulphur compounds during the distilla-

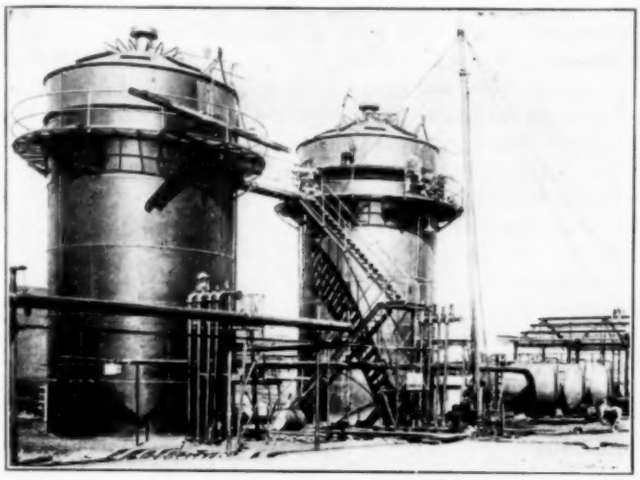

FIG. 4. TWO AGITATORS OF THE LATEST TYPE, 20 FT. IN DIAMETER AND 41 FT. 10 IN. HIGH

tion of petroleum containing asphalt; what role do sulphur compounds take in the condensation of petroleum to asphalt; increasing the efficiency of tower stills, condensers, and heat exchangers; the rapid and effective revivification of spent fullers earth; the separation of the aromatic and cyclic unsaturated hydrocarbons from the paraffine and naphthene hydrocarbons by a more satisfactory reagent than those now in use; the fractionation of petroleum residues containing paraffine wax into a distillate and undecomposed amorphous wax; the elimination of gummy or asphaltic portions from wax distillate by a distillation or mechanical procedure; what constituents of a mineral oil are responsible for the lubricity thereof, and can the lubricating properties of an oil be increased in the light of this knowledge; the prevention of the oxidation of mineral oils in transformers; products which will make emulsions with water without any oil coming to the surface; and a rational plant for producing oil gas from tar and carbon monoxide from the residue, the mixed gases to be suitable for use in gas engines. Then, too, notwithstanding the many processes which have been patented, the "solidification" of petroleum and its products is still under investigation.

The collection of data on the physicochemical properties of petroleum and its products for the use of refinery chemists and engineers is one of the most important inquiries which could be instituted, and it is hoped that the Bureau of Mines will cover this field in its broadest practical aspects. The data obtained on the pure hydrocarbons which exist in crude petroleums also would be of value for purposes of comparison.

"Cracking," or pyrolysis, is regarded as the leading potentiality in petroleum refining, no less so because it permits the production of the main products according to demand, without sacrifice of byproduct possibilities. The importance of the whole matter may be evalued by having regard to the fact that at present, even with "cracking" well launched into practice, less than one-half of the petroleum produced is manufactured into products representing an ideal apportionment of the raw material into its components. The manufacture of gasoline may be doubled eventually or even more greatly multiplied without increasing the production of crude petroleum.

The research activity on the subject of "cracking" has been notable, and the volume of patent applications shows no signs of diminution; in fact, the number of permutations and combinations of the variables borders on the infinite, and accordingly, while modifications of outstanding novelty will be rare, a variety of processes remain to reach the Patent Office. At the present time investigators are endeavoring to obviate the defects in nearly all the methods now in use, which are: (1) the accumulation of carbon, (2) loss of oil as fixed or permanent gas, (3) low yields, and (4) the formation of undesirable impurities.

The inclination to look upon the unsaturated products of "cracking" as valuable for synthetic chemistry is becoming pronounced. The fact that under high pressure the point of molecular scission is directed to the middle of the hydrocarbon chain, while at low pressure the point of rupture is displaced more toward the ends of the chain, holds out additional promise for the working out of commercial processes for the manufacture of isoprene, etc., from petroleum.

An insufficient amount of work is being done in a systematic way to show how to economize in the use of gasoline. A thorough investigation of carbureters and

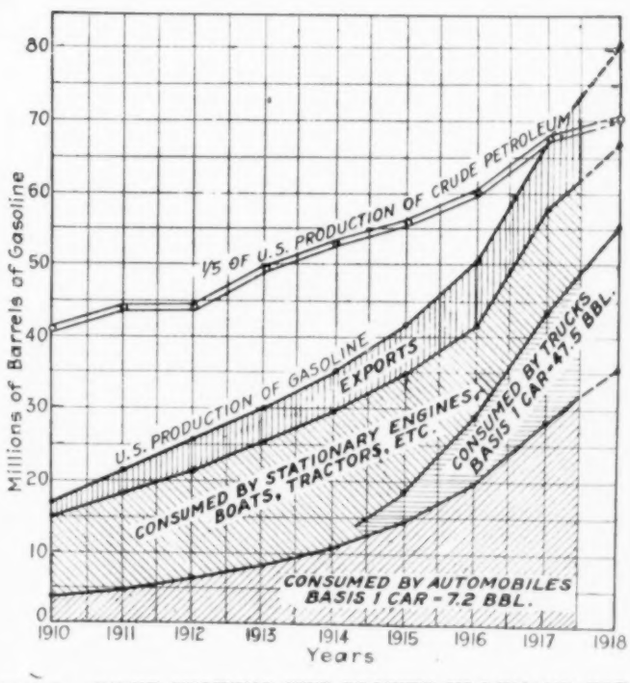

FIG. 5. CURVE SHOWING THE GROWTH IN DEMAND FOR GASOLINE COMPARED WITH THE GROWTH IN OUTPUT OF CRUDE PETROLEUM

fuels, and certified tests of the performance of all makes of automobiles, would be of value in economizing in the use of gasoline, and giving the public as much service as possible for a given expenditure. The Bureau of

Mines and the Bureau of Standards have studied different phases of this question, but neither has been able to conduct as much research as should be done. With over 7,000,000 of gasoline-driven automobiles in daily use, and motor gasoline constantly rising in price, the American public cannot afford to have the Government fall short in a matter of so great economic importance and of serious personal concern to so many.

A very pertinent question is, Should a higher final boiling point for gasoline be permitted? A final boiling point of 230 deg. C. would increase the available supplies by a considerable percentage, while greater efficiency in fractionation would result probably in an additional 10 per cent increase in yield.

Petroleum Substitutes

Even with the most efficient use of the remaining supply of petroleum and an appropriate development of shale oil in prospect, the petroleum situation can be improved additionally by a progressive utilization of substitutes for gasoline and fuel oil, so as to give better economic balance by relieving the products upon which fall the heaviest demands. Two substances, benzol and ethyl alcohol, are suitable for assisting gasoline, and offer the advantage of a record of successful use in motor engines in Europe prior to the war, and of a marked extension of utilization there under the rigorous conditions of the present, while coal and hydro-electricity may be brought to the aid of fuel oil.

Substitutes for Gasoline

The subject of gasoline substitutes is one of particular interest, although definite information concerning it is decidedly limited because of the paucity of research which has been made public. The first point of importance to mention here is that motor fuel is essentially a source of energy and that the energy must come from somewhere. Interesting stories regarding the discovery of new fuels appear from time to time in the newspapers, these fuels often being prepared by adding a small quantity of some secret compound to water. That these "fuels" are one and all without particular value is established by the fact that water contains about as little available energy as any substance which could be selected.

With respect to the real possibilities of gasoline substitutes, it now seems probable that later on shale oil may become an important source of motor fuel. Oil-shale probably will not assume any considerable industrial importance in the immediate future, but its potentiality as a resource gives a comfortable feeling of assurance that the use of motor vehicles will not have to be discontinued when crude petroleum becomes too valuable for fuel purposes. Substitutes for gasoline should receive every encouragement if produced and marketed in an intelligent and scientific manner; for our country needs to increase its motor fuel resources and no step in this direction should be hindered. It should be recognized, however, that petroleum gasoline is a type of fuel for which present equipment has been designed and for which it is eminently satisfactory. It is believed, therefore, that when striking claims are made for the superiority of any gasoline substitute these should not be taken too seriously. The substitute fuel should be given a fair trial, but the user should be satified if it is as good as gasoline and should not expect it to be remarkably superior.

The type of gasoline substitute which is of most importance at the present time is the mixture of hydrocarbons, including benzol, toluol and xylol, obtained as a byproduct in the coking of coal. During the war the benzols were used largely in the production of explosives and other munitions, but since the termination of hostilities a considerable supply has been rendered available for motor fuel. In fact, several companies are marketing benzol mixtures, generally mixtures of the benzols with petroleum naphtha. These products have been used under widely varying conditions, and in most cases favorable results have been obtained.

The use of light oils from coal as motor fuel does not, however, offer an ultimate solution of the motor fuel problem, since the total production of these hydrocarbons is rather limited. The quantity of light oil produced from coal in byproduct coke ovens during 1919 has been estimated at 90,000,000 gal., or about 2.3 per cent of the total amount of gasoline produced in 1918.[13] The actual figure for hydrocarbons suitable for motor fuel is even less than that for total light oil produced, and it appears, therefore, that, as a motor fuel resource, the benzols are of relatively small importance. To illustrate, it may be stated that since 1916 the production of gasoline has practically doubled, while the quantity of coal mined has increased only about 17 per cent. The real importance of the benzols as motor fuel occurs in districts adjacent to byproducts coking operations, where a reasonable proportion of the local gasoline supply may be filled by coal byproducts.

In a certified dynamometer test by the Automobile Club of America 90 per cent benzol showed 12.3 per cent less fuel consumption than gasoline. At the same time the horsepower was increased, depending on the speed. At 2,000 r.p.m. this was 19.4 per cent greater than that of gasoline. The higher ignition point of benzol also eliminates "knocking" (pre-ignition). It is known that the benzols, if properly used, are very satisfactory motor fuels and that there is no difficulty in finding a market for the entire supply.

Ethyl Alcohol as a Motor Fuel

Denatured ethyl alcohol has possibilities for the future and is being developed to a certain extent. It is interesting to note in this connection (1) that fuels with ethyl alcohol base have recently been used with success in motor vehicles in this country, in Europe, and especially in South Africa; and (2) that new sources for the production of ethyl alcohol are being discovered constantly. In addition to the generally known vegetable sources, methods have been developed for the production of ethyl alcohol from sawdust[14], from refuse of cane-sugar manufacture, from waste sulphite liquors, from calcium carbide, and recently, in England, at the Skinningrove Iron Co.'s works, from coke-oven gas.[15] As the largest and best-known field of the consumption of ethyl alcohol in this country has been destroyed for the time being, its use for power purposes would not meet with the competition which it formerly would have had and the price of ethyl alcohol should not be high, especially as compared with the prices of gasoline now prevailing and expected in the near future.

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[13]Even if all our coke were manufactured in byproduct ovens the amount of benzols recoverable would be only about 10 per cent of the annual consumption of gasoline.

[14]It is possible to get 10 to 12 l. of alcohol from 100 kg. of sawdust. There appear to be possibilities in the development of this production of alcohol from wood.

[15]Bury, *Iron and Coal Trades Rev.*, Dec. 19 and 26, 1919.

There are certain difficulties in the way of the wide use of ethyl alcohol as a fuel, which are of a non-technical nature and hence will not be discussed here. It may be stated, however, that the discovery of a cheap, positive and reliable denaturant would go a long way toward making possible the wide adoption of alcohol for power purposes; and that the development of cheaper methods of production and of suitable types of engines are also problems of pertinence.[16]

Alcohol-benzol-naphtha mixtures are in use and have been found to be satisfactory in the present types of automobile engines. "Alcogas" is another product which has aroused interest among automotive engineers.

It would be desirable to institute broad researches (1) on the combustion of alcohol and alcohol mixtures, and (2) on lessening the cost of denaturing. In connection with (1) the operation of a fleet of cars and trucks fed with such mixtures would provide data of importance.

Fuel Oil Substitutes

Fuel oil has come into extensive use in the United States, especially in the far West, as a substitute for coal.[17] It is more convenient than coal and therefore is adopted by industries wherever its price is low enough to permit its use. Its employment in this way cannot be sustained, in view of the slowing rate of petroleum production and the counter-demand that will come in increasing measure from the further development of pyrolytic practice in refining and from the wider adoption of the Diesel type of internal-combustion engine. It soon will be necessary, therefore, in any event, to bring coal and hydro-electric power to the aid of a growing number of those activities now dependent upon oil fuel; and the whole matter may be facilitated by constructive action in respect to coal and water power, to make their service more immediately available.

The use of the tar obtained in byproduct coking (9 to 10 gal. per ton) for fuel, especially in steel manufacture, has increased rapidly during the past few years, and many of the larger steel companies, operating their own byproduct coke plants, do not sell any of their tar for distillation purposes, but use it exclusively for fuel. In open-hearth practice the consumption of tar per ton of steel is reported to be 10 per cent less than the consumption of fuel oil. It is used advantageously in combination with producer gas. The resulting flame has a much better melting efficiency than that of straight producer gas, and the increase in the capacity of the furnace is much greater than would be accounted for on the basis of the heating value of the fuel used. These considerations are of great moment, in view of the increasing price of fuel oil and at a time when the maximum output per unit of investment is essential. The price of approximately 4c. per gal., that has until recently been paid by tar-distilling companies for crude tar, is much too low to meet competition with the real fuel value, and the future is bound to see a scarcity of tar for distillation, which will result in a considerable increase in price.

Increasing the Usefulness of Fuel Oils

It is of interest to note what has been done recently to supplement mineral oils or to increase their usefulness through research. The work has been carried on in several directions, of which the following may be mentioned, without, however, indicating the relative importance of the various remedies.

Processes have been devised for making stable mixtures of tars with mineral oil by using pitch-containing tars, asphaltic residuum and a suitable distillate. It also has been found that fuel oils or residues may be reduced in viscosity by piezochemical means.

During the war the Submarine Defense Association developed the so-called *colloidal fuel*, a mixture of oil and pulverized coal wherein the coal is held in suspension in the oil through the presence of a peptizing agent, called by its inventors the "fixateur." The addition of 1 per cent of "fixateur" to a mixture of 60 to 70 per cent of oil and 40 to 30 per cent of coal dust forms a sort of colloid suspension which remains homogeneous for long periods. It is claimed that this product may be used for oil-fired furnaces in about the same manner as fuel oil, and that it provides (when high-grade coal is used) a fuel of even higher calorific value per unit volume than the original oil.

Next, in particular reference to motor cars, may be mentioned the possible use of *engines of the Diesel type*. Numerous attempts have been made in this direction without noteworthy success, which has been explained by the statement that the Diesel-engine manufacturers are too busy to undertake work on the problem, while motor-car manufacturers do not know enough about Diesel engines. The use of modified Diesel engines on motor cars would relieve the situation to the extent of permitting the use of unrefined oils, instead of only such products as gasoline and kerosene.

The Use of Oil in Gas Manufacturing

It cannot be gainsaid that the use of gas oil, a high-grade fuel oil, in the manufacture of "city gas" is a practice which is unjustifiable on the basis of resource economy. Approximately 6 per cent of our petroleum production is employed for this purpose, and the product is used for cooking and lighting by millions of people and by the industries in a number of ways. A large part of this gas is made by the use of oil to enrich blue watergas of low heating value. Recently this gas oil has become scarcer, and it is likely to become still more expensive and perhaps impossible to obtain in sufficient quantity. This condition will necessitate the use of lower grades of oil, or the production of lower grades of gas, or a change of manufacturing equipment at enormous expense. Individual gas companies cannot investigate so fundamental a question comprehensively; and individual cities or states cannot assume the responsibility of solving the problem for the entire country. The proper agency to take up this question is the Federal Government, with the cooperation of the gas companies and the oil companies and the state and municipal authorities. Such a broad and constructive study would be of high importance and would receive the concurrence of all important interests. It should include research on raw materials, manufacturing methods, and the relative usefulness of the various grades of gas that can be produced.

Research on Chemical Products From Crude Petroleum

Some petroleum economists take the view that later on, when there is evidence that crude petroleum will be unable to compete with its substitutes, it will be

[16] On the comparative fuel values of gasoline and denatured alcohol in internal combustion engines, see Bulletin 43, Bureau of Mines.

[17] The substitution of petroleum for coal has gained considerable headway in the large textile and paper mills, and even in small industries in the New England section.

possible to obtain so many more valuable products from its distillates that the use of any one of these as a fuel will be condemned from the standpoint of conservation. Petroleum then will constitute the basis of a chemical products industry which will be as distinct in scope and activity as the coal-tar industry of the present time. In fact, several of the prominent refining companies have in progress investigatory work which will enable them to accumulate a reserve of technical knowledge respecting the manufacture of various chemical products from crude petroleum.

Some attention has been given to the production of drying or siccative oils from petroleum. It is claimed by the De Bataafsche Petroleum Maatschappij that an oil, the drying properties of which are comparable with those of linseed oil, may be obtained by chlorinating a mineral oil fraction of the specific gravity 0.885 at 15 deg. C., in such a manner that 1,000 l. of it absorbs 800 kg. of chlorine, and then heating the chlorinated product with the addition of zinc dust to 290 to 300 deg. C., until the chlorine has been expelled quantitatively as hydrochloric acid. The problem is to produce an oil economically which will be devoid of tackiness. Artificial resins also may be obtained by the chlorination of petroleum and its distillates; but the reduction of the time of the reaction and the purity of the products present important difficulties. The systematic study of the action of reagents on petroleums—a field which merely has been entered—will provide material for the solution of problems of this character. A subject which already has received some investigation is the conversion of chlorparaffines into esters.

A problem of constant interest is the synthetic preparation of fatty acids from petroleum and certain of its products; for when an economic process is available for the manufacture of these acids a working basis will be had for the production of edible products, some of the acids obtainable being convertible into glycerides. Considerable attention has been and is being given to the study of this problem.

The Russian naphthochemist Zelinskii has been one of the pioneers in the application of the Grignard reaction for the production of fatty acids from petroleum, and so long ago as 1902 he took out a German patent (No. 151,880) for the chlorination of certain petroleum fractions. The fraction 132-145 deg. C. of a Russian petroleum was chlorinated, treated in ethyl ether solution with magnesium and carbon dioxide, and the resulting magnesium salt decomposed with dilute sulphuric acid. An acid, $C_{10}H_{18}O_2$, was obtained which, on heating with glycerine at 250 deg. C., yielded a di-glyceride and a tri-glyceride to the extent of 60 per cent of the theoretical, according to Zelinskii[18]. In normal times, however—that is to say at pre-war prices—this could not have competed with natural fats[19]; but, according to reports, it was otherwise under war conditions, and it has been said that the Vereinigte Chemische Werke a. G., of Charlottenburg, Germany, was able to manufacture fat on a commercial scale by the Zelinskii process.

Chemists who have attempted to repeat Zelinskii's work have found that the yields are very small[20]. The reasons for this are several, the principal among which are the following:

(1) The formation of the magnesium complex is very slow with derivatives containing more than eight or ten carbon atoms.

(2) It is well known that the higher magnesium alkyl halides react with a second molecule of the original alkyl halide to give a hydrocarbon and magnesium halide; for example:

$$C_7H_{15}MgBr + C_7H_{15}Br \rightarrow C_{14}H_{30} + MgBr_2.$$

(3) Brooks has found that the halogen derivatives of petroleum hydrocarbons of ten to twenty or more carbon atoms are unstable and slowly break down on standing at room temperature to give free halogen acids and hydrocarbons which appear to be mainly saturated ring compounds.

(4) Stadnikov[21] has demonstrated that the alkyl magnesium halide and ether complex breaks down in a variety of ways. For example, Stadnikov showed that a complex made from magnesium propyl iodide, carbon dioxide and benzhydrylbutyl ether yielded a mixture of several hydrocarbons, free carbon dioxide and mixed ethers, only a trace of acid being obtained.

Schultz in 1912-13 studied the oxidation of mineral oil fractions; but the percentage of fatty acid obtained was stated to be very small, the main oxidation products being aldehydes. Some of the best results are said to have been obtained by the oxidation of paraffine[22]. The Chemische Fabrik Troisdorf (Drs. Hülsberg and Seiler) has patented the following method: Air or oxygen is led into a vessel containing melted paraffine, for about fifty hours, at a temperature of 100 to 120 deg. C., mercuric oxide or previously oxidized paraffine being utilized as a catalyst. It is said that the products consist partly of oleic acid and partly of volatile substances, but nothing definite has been divulged respecting the yields of oleic or other fatty acids. A somewhat similar method is that of the A. G. für Mineralölindustrie vorm. (David Fanto & Co.), of Pardubitz, Bohemia. It has been stated that this firm has been working on a large scale, since 1915, a process which consists mainly in blowing air into paraffine for fifteen to eighteen days at a temperature of 130 to 135 deg. C. (See also English Patents Nos. 131,301, 131,302, 131,303, and 133,027.) The yield is calculated at about 60 per cent. According to reports, a fatty acid, $C_{11}H_{22}O_2$, of melting point 53.7 deg. C., thus has been obtained, together with an iso-palmitic acid, $C_{12}H_{22}O_2$, of melting point 38.4 deg. C., and lignoceric acid, $C_{24}H_{48}O_2$, of melting point 80 deg. C.

The methods so far known are considered to be of practically no value for preparing fatty acids from petroleum, even for the purpose of laboratory research. In illustration, it may be mentioned that hydrogen and fatty acids result from the fusion of the higher alcohols with potassium hydroxide, but only the higher primary alcohols give good yields. The secondary alcohols are slightly oxidized under these conditions and yield mostly condensation products, while the higher tertiary alcohols break down, giving acids having a less number of carbon atoms. Moreover, it has been shown that the alcoholates of the higher alcohols react with carbon monoxide under high pressures, but the principal products formed are esters of formic acid and not the higher fatty acids. The known methods for preparing alcohols direct from petroleum olefines yield only secondary and tertiary alcohols. And then no methods for

[18]See *Z. angew. Chem.*, vol. 16 (1903), p. 37.
[19]Colletas, *Mat. Grasses*, vol. 7, (1914) p. 4,151.
[20]Brooks, MET. & CHEM. ENG., vol. 18 (1918), p. 388.
[21]See *Ber.*, vol. 44, p. 1,157; vol. 47, p. 2,133; *J. Russ. Phys. Chem. Soc.*, vol. 47, pp. 1,122, 2,037, and 2,115.
[22]Cf., however, Wegrzyn, *Petroleum*, vol. 13, p. 24, who made entirely unsuccessful attempts to obtain fatty acids from solid paraffine.

adding halogens or halogen acids to the saturated or unsaturated hydrocarbons are known which give satisfactory yields of primary derivatives.

A variety of methods also have been proposed for oxidizing saturated and unsaturated hydrocarbons by air in the presence of various other substances and many wet methods have been tried, but in general the results are carbon dioxide, water, resinous or asphaltic material, and traces of the simple fatty acids, such as acetic, propionic, butyric, etc., which usually have not been obtained in quantities sufficient for positive identification. Our knowledge of hydrocarbon chemistry is unsatisfactory, and hence in real need of the revision of research. The commercial production of fatty acids from petroleum may some day be accomplished, but not by the methods of synthesis now known and not until there has been obtained a much more extensive and quantitative knowledge of the nature and behavior of hydrocarbons, such as constitute petroleum oils.

The lowest boiling fraction of petroleum, of the composition C_5H_{12}, may be used for the preparation of isoprene: by systematic chlorination, isomerization and liberation and addition of hydrochloric acid, the three hydrocarbons present (iso- and normal petane and tetramethylmethane) all can be converted into isoprene. But much more investigation will be required before carbon complexes.

It is thought that a simple, direct process for obtaining the butadiene hydrocarbons from petroleum soon will be found, and thus a good route to synthetic rubber will be opened up. Pyhälä has shown that the fraction of Baku petroleum boiling between 98 and 106 deg. C. yields up to about 20 per cent of its weight of adipic acid, which, by way of the amide, can be converted into butadiene.[23] This method of preparation is, however, hardly possible from a commercial standpoint, and butadiene usually is obtained technically from benzene or phenol.

It is of interest to mention in this place that the emulsions obtained with the turpentine-like and other hydrocarbons of petroleum by the aid of certain emulsifying agents are similar to rubber latex and can be worked up into rubber-like products.

Finally, it may be noted that the production of dyestuffs from petroleum is an open field for research exploration. Kharitchkov[24] has found that the nitro-derivatives obtained by treating machine or spindle oils with warm nitric acid (specific gravity, 1.50) are related to the nitro-compounds obtained by nitrating polynaphthenic acids and used in the preparation of dyestuffs. Nitro-products which yield with alkalis brown substantive dyestuffs and with sulphur and alkalis brown to brown-violet sulphur dyestuffs have been obtained by the nitration of the higher fractions from Galician petroleum.[25] The preparation of aromatic hydrocarbons from fatty hydrocarbons—especially the preparation of benzene and its homologues from petroleum—requires investigation along broad lines, although the subject is not of technical interest here at present. Crude petroleums from some Bornean and Persian fields are aromatic-rich and provided toluene for TNT manufacture during the European war.

While one-fifth of the domestic consumption of petroleum is utilized as fuel, most of the crude oil is refined into products which possess wider usefulness and higher value to society than the raw material, and refining practice is in continuous flux to adapt petroleum to a varying and widening demand. Under present technical procedure, however, petroleum yields only several hundred substances of commercial importance, but no limit can be set to the number of useful products that scientific inquiry may wrest from this raw material. Indeed, the field of petroleum byproducts represents one of the most attractive research opportunities that exist in this country today. It has been observed by Gilbert and Pogue[26] that—

> In this connection an interesting vision opens up as to how a great oil byproducts industry, through the values accruing to successive refinements of products, may be led to contribute more than it now does to the expense of petroleum production, relieving to that extent the cost distributed among the products universally used in bulk, such as gasoline. It would seem that a far-sighted economic policy, properly directed, might eventually contribute to a lowering cost for motor fuel, just as a proper shaping of coal economics could be made to relieve the focus of expense now exclusively borne by fuel coal—the two conspiring to lower the cost of living.

The time may be foreseen when, through the accomplishments of technochemical investigation, the petroleum industry will yield a range of fuels for the internal-combustion engine only; kerosene in quantity narrowing to that desirable for country use and export trade; lubricating oils adjusted to the growing demands of mechanical power; and an ever-widening range of chemical products supporting a great petroleum byproducts industry, rivalling if not exceeding the coal-products industry in importance. In respect to the last, it should be emphasized that the United States today faces an opportunity similar to that which twenty years ago confronted both Germany and the United States as regards the manufacture of dyestuffs, explosives, fertilizers, drugs and other chemicals from the non-fuel components of coal.

The Need for Petroleum Section of the American Chemical Society

The recognition of the high value of science to industry has led to the adoption of systematic procedure in the collection and diffusion of technical information, and the tendency in all civilized countries is more and more in the direction of increased specialization. For example, the very comprehensive subject of chemistry no longer is represented by a unicameral society or by periodical literature dealing with it in an all-embracing manner; and while the multiplication of organizations and journals is attended with obvious disadvantages, it is recognized generally that these are offset largely by the resulting benefits, and that the interest of those engaged in any important industry can be promoted most satisfactorily by affording facilities for assembling under a distinctive banner.

The position to which the petroleum industry has attained, technically and scientifically, is such that the creation of a separate organization for the benefit of those chemists who are engaged actively in it is fully justified. In 1913 there was formed in England the Institution of Petroleum Technologists, constituted principally of chemists and chemical engineers employed in the petroleum and shale-oil industries; but so far nothing has been done, in a national way, in the United States.

The several petroleum refiners' associations afford

[23] *Petroleum*, vol. 9 (1914), p. 1,376.
[24] *Chem. Ztg.*, vol. 37 (1913), p. 869.
[25] See Freund, *Z. angew. Chem.*, vol. 25, p. 1,058.
[26] U. S. National Museum, Bulletin 102, I, ii.

ample machinery to care for questions of general policy, internal and external, affecting the petroleum industry of this country. These are, however, strictly trade organizations. Without the desire to inflict any additional cares upon the industry, which now has its hands full in supplying pressing commercial needs, opportunity is taken here to indorse the formation of a petroleum section of the American Chemical Society, a move recently proposed by a group of chemists professionally interested in petroleum and its refining.

To rest content with the present status of the petroleum industry would not be characteristic of this nation, which is justifiably proud of its initiative, resourcefulness and inventive spirit. New lines must be developed and advances must be made in technical methods, if we are to progress adequately. No surer provision could be made for these efforts than the semi-annual gathering of the research men from the various petroleum laboratories, into the atmosphere of a great assemblage of chemists. The presentation of papers and their discussion would establish facts of value to all, broader viewpoints would be obtained, and sympathetic personal relationships formed which would stand to good advantage.

It is natural perhaps that each commercial organization should desire to retain for itself the benefits of research conducted under its auspices, yet, carried too far, it is a short-sighted policy in view of the varied workings of different minds. Community of knowledge as to scientific achievements, safeguarded by the critical discussion of experimental results, has proved to be so valuable a means of technical advancement that it should not be neglected in the petroleum industry.

The objects of a petroleum section of the American Chemical Society should be along the following general lines:

(1) To enable chemists and technologists engaged in the petroleum, shale-oil and natural gas industries to meet and to correspond, and to accumulate trustworthy information regarding the occurrence and production of petroleum, oil-shale and natural gas, the conversion of the raw materials into manufactured products, and the characteristics and usages of these products, together with their transport and storage.

(2) To promote the better education of persons desirous of becoming petroleum engineers, refinery engineers or hydrocarbon chemists, and to elevate the professional status of those employed in the industries mentioned by establishing a high standard of scientific and practical proficiency.

(3) To encourage research in hydrocarbon chemistry.

(4) To co-operate with the American Petroleum Institute and with the National Research Council, and to collaborate with the American Society for Testing Materials in its work on the standardization of bituminous and petroleum products.

Petroleum and the European War

It has been said that the success of the Allies in the European war was due largely to the supply and utilization of petroleum. Certainly, as Dunstan has remarked,[24] without mineral oil warfare would have remained in a mediæval condition and an impasse might have resulted. As we now know warfare, it is impossible to conceive of strategy and tactics deprived of oil-fired ships, motor transport, aircraft, tanks, and flame projectors, while industry at home lacked internal-combustion engine fuel and lubricants. The vital importance of the reaction of petroleum on the great struggle was pointed out clearly and forcibly at the annual dinner of the Institution of Petroleum Technologists last year.[25]

The principal problems confronting the Allies were:

(1) Whether the world could produce the aggregate supplies that were required for the service of the war.

(2) Whether the processes of refining could be so adjusted that increased quantities of heavy fuel could be obtained as well as of gasoline, particularly of the high grade required for aviation purposes.

(3) Whether sufficient tankers, cars and receptacles could be provided to transport and distribute by sea and land the necessary quantities of each product.

All these problems were solved satisfactorily—a fact which reflects the greatest credit to the large petroleum companies as well as to those who acted for the governments.

An enormous amount of intensive research was initiated throughout the war, and it is not too much to state that a wider and deeper knowledge of naphthology is one of the good results of the conflict. Immediately after this country entered the war the splendid facilities of the laboratories of the important refining companies and of the Bureau of Mines were offered to the War Department for experimental work, and the acceptance resulted in considerable investigational work. Perhaps the most valuable contributions were made on fuels for airplane motors, products of "cracking" processes, lubricating oils and the inspection of fuel oils. The standardization of motor gasoline and lubricating oils, and specifications therefor for Government purchase, emanated from the committee on the standardization of petroleum specifications of the Fuel Administration.

Need for Petroleum Production Engineers

The United States Bureau of Mines points out strongly the need for petroleum production engineers who shall apply their scientific and geologic training to oil field development work and to the improvement of the processes of extraction from the ground of all the recoverable oil.

One of the hard problems to contend with at the oil wells is that usually there exist strained relations between the technical and non-technical men, although there is no logical reason why most cordial relations could not be established between the petroleum engineers and the other employees. A little leniency ought to be shown on both sides. It would be a good policy for engineers to discuss with the drillers the daily well reports.

According to Bulletin 195, "Underground Conditions in Oil Fields," the duties of experienced petroleum engineers might be outlined as follows:

(1) Keeping of records.
(2) Preparation of data, such as production records, well logs, structure contour maps, cross-sections, etc.
(3) Correlation of surface and underground geology.
(4) Water problems.
(5) Casing depths.
(6) Underground losses.
(7) Oil sands; location of productive sands, their thickness and quality of oil.
(8) Well depths.
(9) New well locations and extension of the field.
(10) Future well production.
(11) Gaging of oil wells.
(12) Perforations and setting screen pipe.
(13) Fluid levels and tubing depths.
(14) Shooting of oil wells.
(15) Methods of extracting more oil from the oil-bearing formations.

[24] "Reports of the Progress of Applied Chemistry," vol. 4 (1919), p. 66.

[25] *J. Inst. Pet. Tech.*, vol. 5 (1919), p. 221 *et seq.*

Physical Chemistry and Technology

Progress of Technology Dependent on Existing Physicochemical Knowledge Being Interpreted and Applied as Well as Augmented—Empirical and Scientific Solution of Problems—Physicochemical Data—Co-operative Research

BY EDWARD W. WASHBURN

THE writer has given elsewhere the following definition for the term physical chemistry: "Physical chemistry, sometimes called also theoretical or general chemistry, treats of the fundamental laws and principles and the important theories and systems of classification which have been formulated in order to give scientific expression to our knowledge of the physical and chemical behavior of material substances." Scientific expression of our knowledge of any subject is that expression of it which enables the human mind to acquire this knowledge in as complete a form as possible with a minimum expenditure of effort. Such a definition, in a sense, might be said to include the whole of both physics and chemistry and it is, of course, impossible to draw any sharp line between the two sciences or between either of them and that borderland region to which the term physical chemistry is ordinarily applied.

With such a definition of physical chemistry, it would seem almost unnecessary, if indeed not quite superfluous, to dwell upon its importance to the whole field of chemical technology, and therefore in responding to the editor's request for a contribution on this topic, I shall attempt only to set forth briefly two outstanding features of the work of the physical chemist in its relation to industrial progress.

These two features may briefly be described as follows: (1) Knowing how to find, interpret and apply existing knowledge; and (2) knowing how to set to work in a scientific manner to acquire necessary new knowledge; the term *scientific* being here employed with the significance attached to it in the definition of physical chemistry given above.

THE USE OF EXISTING SCIENTIFIC KNOWLEDGE

A good working knowledge of physical chemistry enables the industrial scientist to make use of a wealth of scientific data which would otherwise be largely unintelligible to him, the bearing of which upon his own problems he would otherwise be unable to perceive. How many chemical engineers, for example, without a working knowledge of physical chemistry would, if faced with the problem of perfecting a process for the production of pure hydrogen on a large scale, expect to find information worth considering in papers bearing such titles as "The Phase Rule Diagram of the System Iron-Oxygen," "The Electromotive Force of the Cell Zn-Saturated Solution of ZnO in NaOH-NaOH-H_2," "The Free Energy of the Reaction Between Steam and Metallic Iron," "The Free Energy of the Water Gas Reaction" or "Selective Catalysis"; or having such an expectation, how many would be able to understand and make use of the information there given? It is unquestionably possible even at the present day to publish in a scientific journal of wide circulation a contribution containing results of fundamental importance to an industry representing investment of many millions of dollars and to have this contribution remain entirely unknown to those engaged in this industry.

During the last few years we have been hearing, and rightly so, a great deal about the importance to our national welfare of greatly increased facilities for scientific research, but in urging the importance of such research to the industrial progress of the nation we should not forget that such progress does not result from the mere acquirement of new knowledge. The acquirement must be followed by utilization. I think it may be safely stated that the amount of progress, if it could be measured, which would result during the next decade from a complete utilization by the industries of the country of the scientific knowledge already extant would be quite as great as that which will result from the new discoveries of research workers, important as the latter are sure to be. In urging, therefore, the importance of scientific research, it should be remembered that such research will promote industrial progress only in so far as industry supplies the machinery for putting the new knowledge into effect, and in so far as any industry fails to apply extant scientific knowledge, just so far are the results of future scientific research likely to be barren of practical results in that industry.

It so happens that some of the most backward of the industries in making use of modern scientific knowledge are to be found among those industries which were earliest developed by mankind, such for example, as the tanning industry, the textile industries and the glass and clay products industries, while others of this group, such as the brewing industry and metal-working industries, have made extensive use of the modern scientific methods. Such a backward condition, while deplorable from the modern scientific viewpoint, is a perfectly natural one, because the progress, in many ways remarkable, which has nevertheless been attained in these "backward" industries, represents the accumulation of centuries of hard experience, gained by the slow processes of trial and error, in many instances, long before the development of science itself. Knowledge gained in this way tends to produce extreme conservatism in those who possess it, together with a general skepticism regarding the value of anything which a chemist, who knows nothing about the industry, can accomplish. Fortunately, this condition has now largely disappeared, the last ten years having seen a great change in the attitude of many of the older industries toward the value of applied sciences.

The training of the physical chemist, including as it does (or should) the fundamentals of chemistry, physics and mathematics, as well as those of that borderland science more strictly included under the term physical chemistry itself, is peculiarly adapted to the production

of a mind trained to appreciate, understand and apply a wide range of scientific knowledge. Thus while each industry will naturally employ specialists in those branches of chemistry or physics touching most closely upon its own special field, *every* industry could to advantage make use of the services of a physical chemist, and no industrial research laboratory is complete which does not have available the services of at least one physical chemist. It is true that there are physical chemists and physical chemists and the writer knows of no safe criterion of selection other than the Biblical one, that a man should be judged by his works, and as long as there continues to be an inadequate supply of well-trained men in this field, there will inevitably be disappointments in what some of them will be able to accomplish.

The most important feature in the training of every physical chemist is the development of the reasoning powers, the powers of analysis, the ability to weigh and judge and to bring to bear upon a problem the attitude of mind and the scientific instinct of the chemist, the physicist, the mathematician, and finally, when it comes to a question of industrial application, also of the engineer. This is admittedly a large requirement, but in so far as it is attained the ideal physical chemist will be produced.

One maxim which should be impressed upon all students of physical chemistry is the following: *No one can safely use a mathematical relationship, the derivation of which he does not entirely understand.* Nor is it sufficient that he should once have understood it; the essential features of that derivation and all the factors which it involves must be kept constantly in mind. There are unfortunately in the literature numerous examples of attempts to apply some equation or law of physical chemistry to a case which does not come under it at all, or which fails to meet one or more of the assumptions upon which the law is based. In fact it is always safer to derive the desired equation for the particular case at hand rather than try to adapt a more general relation to a special case. It is because of this lack of a thorough understanding of the laws of physical chemistry that so many chemists go wrong when they attempt to apply these laws to particular cases. In fact, it is so easy to go wrong in this particular—to forget for the moment the precise significance of some term in a thermodynamic relationship, for example—that instances of this character can be found in the writings of the most eminent authorities in this field. There is, of course, no absolute guarantee of avoiding occasional mistakes of this character, but the chemist who can go back to first principles is less likely to err than the one who attempts to use a relationship in a mechanical fashion. The philosophy of science as treated by such writers as Poincaré, Mach, Enriques, Russell, etc., should be included in the education of every candidate for a doctor's degree in physical chemistry.

The Acquirement of New Knowledge

We may distinguish two classes of methods of attacking a research problem. One of these, the empirical or cut-and-try method, tries one thing after another, systematically and intelligently, it is true, in the hope that the desired solution may eventually be hit upon. The scientific method, on the other hand, first studies and analyzes the problem in the light of all the data which physics and chemistry can supply and finally outlines a method of attack which will yield as complete a knowledge, both qualitative and quantitative, as may be, of the factors involved in the problem, the why and wherefore of these factors, and their relation to other associated questions, and when the solution is finally obtained there is a reasonable degree of certainty that it is the best one, everything considered.

The Empirical Solution

The first method is easier to carry out, requires the consumption of less gray matter, and has many times been productive of important results, although the percentage of successes may seem larger than it is, because the failures are usually not recorded. The first method may, moreover, yield much quicker results than the second, but on the other hand, it may never yield any results at all and if, as is sometimes the case, it is carried out on a factory scale, it may prove exceedingly expensive. If the investigator is lucky, however, he may hit upon a solution in the factory itself, and if so, he may feel well satisfied with himself, as a "practical" man, who has found a "practical" solution to a "practical" problem without wasting a lot of time and money on "highbrow stuff." The fact that he may have more or less stumbled upon a solution and that he frequently has not the ghost of an idea (or else a very wrong idea) of what was back of his problem, or why his solution was a solution, or how long it will remain a solution ought to warn him that hand-to-mouth research, even when successful, still leaves much to be desired.

The Scientific Solution

The scientific method, while slow perhaps, is reasonably sure, its results are of permanent value and carry with them a feeling of confidence and surety which those of the empirical method largely lack. In practice, the two methods, of course, merge into each other more or less. Whenever the scientific analysis of a problem shows that little or no help is obtainable from existing scientific knowledge, recourse must naturally be had to the empirical method or else a new domain of science must be opened up and explored, and naturally few industrial problems can wait for the progress in pure science which might be required before the scientific method could be strictly employed. This was approximately the state of affairs a few years ago with respect to those industrial problems which today would be classed as problems in colloid chemistry.

Physicochemical Data

The physical chemist who undertakes to apply his science to industrial problems will often find himself confronted with the following situation: The scientific analysis of the problem is fairly easy—sometimes, in fact, ridiculously simple. The principles involved and the manner of their application are quite obvious, but when he sets to work to solve the problem he finds that the literature fails to give him the necessary physicochemical data in numerical form. A phase rule diagram is missing, the free energy of some reaction has not yet been determined, certain data on specific heats or solubility or what not are lacking. A whole set of problems in pure science is uncovered the solution of which must precede the attack on the main problem by other than an empirical procedure.

The writer was called upon recently for advice in connection with the production of a material which should be suited as perfectly as possible to withstand

certain conditions. On investigation, it was clear that the direction in which the solution of the problem was in all probability to be found could be perfectly definitely stated in approved physicochemical terms, using the letters, *a*, *b*, *c*, etc. (or α β γ, if preferred) to represent certain quantities, but that was as far as physical chemistry could go. The numerical values represented by the symbols had never been determined and although their determination offered no particular difficulty from a scientific point of view, a rather lengthy and, for the company's interest, expensive investigation would have been required. Moreover, while it was evident that such an investigation was of fundamental character to this branch of the company's activities, it was just as important and fundamental to a great many other companies engaged in the same business and it was not clear that the financial gain would be sufficient to justify the expense being borne by one company.

Co-operative Research

It is just here on problems of this character that co-operative research needs to be developed. The resources of the universities and of endowed research foundations are not sufficient to keep the progress in pure scientific research up to the demands of the industrial world. Either the industries must themselves enter this field on an extensive scale (as some of them have already done) through co-operative research organizations, or in their own research laboratories, or they must come more strongly to the aid of universities, or preferably both. In fact, if the latter course is not pursued, they will soon destroy the possibility of entering upon the former.

Influence of Mathematical Speculations on the Progress of Chemistry

The May, 1920, issue of *Chimie et Industrie* publishes *in extenso* the lecture given by Prof. Henry Le Chatelier before the French Society of Industrial Chemistry on the great importance of applying higher mathematics to the study and interpretation of chemical reactions and on the furtherance of chemical research work.

He dwells strongly on the needs of the higher general scientific education for the chemist and cites cases where work on chemistry of the greatest industrial importance was brought to successful results not by men who had received only a purely chemical education but by those who had received a solid theoretical education in well-known engineering schools. This is illustrated by the work of men like Osmond, Deshayes, Charpy, Guillet, Bied and Taffanel, all graduates from the Paris schools of Polytechnics, Centrale or Mines, where they could not have received sufficient experimental training but where they acquired a solid scientific education which soon enabled them to become leaders in the chemical research field. If engineers could become so successful chemists, how much greater expectations might be surmised were the chemists to possess also the fundamentals of higher mathematics.

He proposes the formation of special schools of chemistry on lines similar to those of the Paris special school of electricity where only bearers of diplomas from well-recognized educational institutions shall be enrolled. Thus only will it be possible to train a growing number of men theoretically and practically well prepared to direct the chemical industries.

He suggests a program for the organization of the staff of chemical plants. This program calls for a director who shall have the above-outlined theoretical and practical education and whose duties shall be to submit to the chief of the laboratory chemical problems and act in a consulting capacity for the solution of such problems. The chief of the laboratory shall outline and direct the laboratory work, devise the appropriate experimental methods, apportion the work among his assistants, control the exactitude of the experimental results, and interpret these results. At present there are no special schools from which men prepared for such work might be recruited. The laboratory assistants shall be experimenters in physics or chemistry, specialists in their line of work. They could be recruited in a satisfactory manner from the now existing schools of chemistry. The help for doing the more or less routine work could be recruited from those with some easily acquired experience in the required line of work.

Prof. Le Chatelier considers the problem of training men for the task of chief of a laboratory of prime importance and dwells especially on their need for quite a thorough knowledge of special mathematics. He illustrates with facts the application of the notion of continuity to the interpretation of the theory of solubility, the utilization of geometric representations especially for the outline of programs of experimental work, the generalization in solving chemical problems by the use of logarithms and a better co-ordination of experimental results and minimizing the experimental errors by applying the fundamentals of the calculus of probabilities.

It is especially in the practical application of chemical mechanics that mathematical knowledge is of great importance. All the laws of chemical mechanics are exclusively of mathematical origin. The number of these laws is small, but their rigorous exactitude makes them particularly useful. He passes them in review and illustrates their importance by enumerating some of their applications. Thus:

The law of factors of equilibrium has served to explain the function of catalyzers in chemistry as being similar to that of lubricating oils in mechanical apparatus.

The law that two systems in equilibrium with a third are in equilibrium with each other and reciprocally has been successfully applied by van't Hoff to the study of the vapor tension of efflorescent salts.

The law of the stability of equilibrium has been used in solving the problems of a better utilization of the sensible heat of gases and is applied to the now rapidly growing industry of synthetic ammonia.

The law of phases has enabled van't Hoff, Bakkhuis, Roozeboom and their pupils to solve the complicated systems of acid solutions of iron chlorides and of the sea water salt solutions. The same law led van't Hoff to establish his dilatometric method to the solution of chemical problems.

The law of iso-equilibrium established by Clapeyron in the particular simple case of vapor tension has been generalized by Thompson to fusion phenomena. This law, combined with the law of mass action of gaseous systems, has been successfully applied to the synthesis of nitric acid by the electric arc.

He concluded with the plea for changes in the educational programs of colleges and universities and for the formation of special schools of chemistry for the theoretical and practical training of chief chemists and chiefs of chemical laboratories.

Relation of Chemical Engineering to Sewage and Trade Waste Treatment

A Brief Outline of the Methods of Sewage and Trade Waste Treatment—The Activated Sludge Process and the Chemical Engineering Problem Involved in Pressing and Drying the Sludge

By R. H. EAGLES*

THE development of municipal sewage disposal in the United States has made great strides in the past decade by virtue of the progressive and forward-looking spirit of our fast-growing cities. Impetus has been given to the movement by the natural influence of the many public welfare campaigns for which this country is distinguished.

In Great Britain and Continental Europe, where residential and industrial habitation is extremely dense, adequate sewage disposal equipment is a universal necessity, because the public waterways—the natural scavengers—cannot stand the concentrated load of raw sewage which they must otherwise carry.

American engineers are anticipating this condition and are devoting their energies to the development of a standardized system or systems which can be applied to any set of local conditions with pre-assured success. The matter of operating expense is in most cases the governing factor, and this has given rise to many efforts to recover commercially the valuable elements which are known to be present in the wastes. Attempts along the latter line have been only partly successful to date in that the valuable constituents have been reclaimed in concentrated form as solids, but the final economical preparation, in marketable form, has proved the stumbling block.

It is toward the solution of this problem, which is in reality of a process nature, that the services of the chemical engineer should be impressed. He alone of the engineering profession is best adapted by training and experience to work out the details which involve principles of physical chemistry and the mechanics of pressing, conveying and drying. He is also well equipped to prepare his product in the best shape—chemically and physically—to assure its ready demand and highest value.

Methods of Sewage Treatment

To be specific, one of the most important problems facing sewage treatment development today is to find a satisfactory means of dewatering and drying activated sludge and converting it into a marketable fertilizer. Before elaborating on this problem a brief sketch of sewage treatment methods may be of interest.

When the disposition of domestic wastes by water carriage came into general use it immediately presented the problem of reseparating the waste materials from the water at a community or municipal plant. This became necessary for the protection of public health from drinking water pollution and for æsthetic reasons involving the visible evidence of wastes in the public waterways. In the case of towns and cities located on the seacoast the simplest method, and one which is still generally in use, lay in carrying the wastes into the sea, where the extremely high dilution soon obliterates all traces of pollution.

The objectionable constituents of domestic sewage consist chiefly of unstable organic compounds in solution and suspension. The compounds undergo more or less rapid decomposition and furnish nuclei for the propagation and subsistence of disease-producing bacteria which are also present.

Among the methods of sewage treatment which have been used, either alone or in combination, are the following:

1. Mechanical Fine Screening.
2. Sedimentation.
   - (*a*) Straight sedimentation with sludge removal.
   - (*b*) Imhoff sedimentation, with self-contained sludge digestion.
   - (*c*) Septic tank sedimentation with self-contained sludge digestion.
3. Chemical precipitation (followed by sedimentation).
4. Sand filtration.
5. "Sprinkler" or "trickling"—aërating filters.
6. Contact beds.
7. Chlorination.
8. Electrolytic oxidation.
9. Activated sludge.

The various features and combinations which apply to these methods are too numerous to describe, but it is the purpose of this paper to present some of the features which may be of active interest to the chemical profession.

The Activated Sludge Process

The activated sludge process of sewage disposal has come into prominence within the last few years. It employs the use of aërobic, or oxygen-consuming, bacteria for the purification of the sewage. The biologic growth is first developed and cultivated, and it then propagates and is kept alive by the constant addition of fresh sewage, the impurities of which supply the food, and air, which is used both for agitation and as a supplementary food. This method has proved highly satisfactory as regards the production of a clear, stable effluent, and it has reduced in many cases a sludge containing considerable fertilizer value in the form of nitrogen compounds. The control of the bacteria and the means of increasing their nitrogen-retaining ability extend into the field of chemistry.

Another phase of the activated sludge proces-

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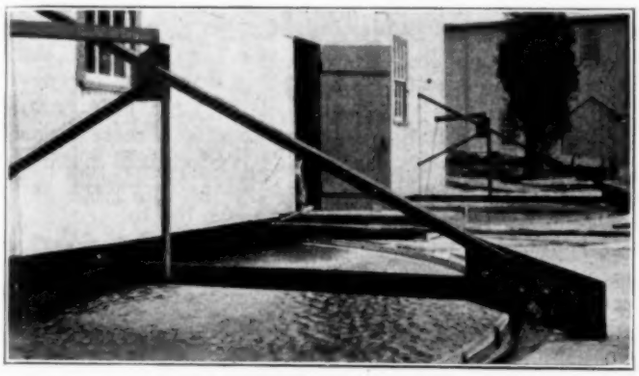
which should receive the attention and study of chemical engineers is the design of apparatus which will economically introduce the air and maintain a prolonged, intimate contact with the fresh sewage and the bacterial flocs. The greatest cost of the process is that of supplying compressed air. Many experimenters have relied too much on the use of the air to effect agitation and circulation, in addition to supplying the really minute oxygen requirement of the bacteria.

It has been calculated that the actual oxygen requirement could be theoretically satisfied by the addi-



CLARIFYING TEXTILE MILL WASTE WATERS AND REMOVING THE IMPURITIES AFTER CHEMICAL PRECIPITATION AND COAGULATION

tion of 0.05 cu.ft. of air per gal. of sewage treated. The average optimum practice of a number of experimental stations in this country and England has shown a requirement of 1.5 cu.ft. per gal., or thirty times theoretical.

A more recent modification developed at a test plant at Mount Vernon, N. Y., has reduced this requirement to 0.5 cu.ft. per gal., one-third the usual amount, but still ten times theoretical. The reduction at this plant is due partly to a mechanical design which insures prolonged and intimate contact of the air bubbles with the sewage, at the same time utilizing the maximum mechanical efficiency of the air for circulation purposes.

Here again is an inviting field for chemical engineering research. It is, strictly speaking, the problem of absorption of a gas in a liquid, the elements being air and sewage.

This leads to a closely allied feature of the process which has not yet been perfected—namely, the matter of air diffusion. Various types of porous media such as filtros tile, basswood blocks, cement and sand preparations have been tried with varying degrees of success, the desideratum being an air bubble of sufficient fineness to prevent its coalescing because the minute bubbles offer more contact surface. Practice in this country has inclined to the use of filtros tile as the best-adapted medium, but it is an open question whether ejectors or some type of spraying device may not economically substitute for diffusion media entirely.

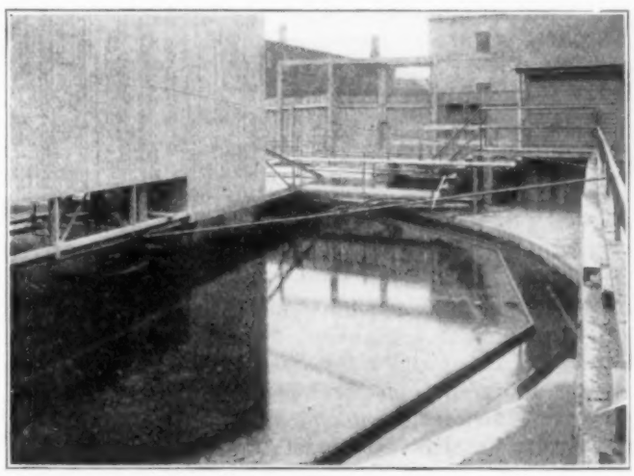
By far the most important problem in connection with the activated sludge process, as mentioned before, is the disposition of the resulting sludge. The activated sludge itself is a biologic growth of flocculent structure, and under proper conditions should contain from 3 to 6 per cent nitrogen on dry basis, expressed as ammonia. In view of the present market price and demand for nitrogen fertilizer it is readily seen that a promising field of investigation is opened up in the commercial reclamation of the sludge.

Problems of Pressing and Drying the Sluge

The flocculent nature of the sludge prevents its concentration by straight sedimentation, although it can be reduced to 97 per cent moisture by mechanical dewatering devices, as has been demonstrated by the use of a Dorr Sewage Clarifier at the Milwaukee test plant. Centrifuging will further reduce the water content by approximately 90 per cent, but the definite advantage to be obtained by this expensive intermediate step has not yet been demonstrated. The use of filter presses of various types has been tried with mediocre success. The sludge flocs on pressing revert to a jelly-like mass which clogs the pores of the filter cloth, resulting in an expensive and inefficient procedure. The sludge decomposes rapidly to an unfilterable mass, and this factor must be carefully watched.

Various experimenters have been using filter presses even under the trying conditions and producing a filter cake with moisture content sufficiently reduced to permit of feeding to a drier. Mechanical conveyor difficulties have been encountered, and an appropriate drier has not yet been determined.

It may be said without exaggeration that further development of this very desirable method of sewage purification will be held at a standstill pending a successful method of pressing and drying the sludge. It is not unreasonable to expect that helpful suggestions, and possibly a successful solution of the prob-



TANNERY SEWAGE CLARIFIER IN OPERATION, REPLACING AN OLD "FILL AND DRAW" SYSTEM

lem, will come from the chemical engineering profession, where similar problems have been encountered and solved.

Sedimentation

The foregoing will serve to point out the immediate problems of the activated sludge method of sewage treatment. Another distinct system of treatment which is coming into prominence, particularly in England, is the use of straight sedimentation for the removal of all solids which will settle, followed by treatment of the clarified sewage by biologic or chemical final purification. The settled solids are removed in the form of thick sludge for disposal by biologic diges-

tion or by natural draining and carting-away methods. This system offers the advantage of low operating costs, but does not offer the recovery values of the activated sludge process because the nitrogen values must finally be carried away in solution, preferably as innocuous nitrates.

A careful study of sedimentation principles is entailed by this system, which may be said to lie within the field of physical chemistry. The mechanics of

TANNERY SEWAGE CLARIFIER (UNDER CONSTRUCTION) CLOSE TO RESIDENCES. NO FLIES, ODORS OR OTHER NUISANCE RESULTS FROM ITS OPERATION

performing efficient sedimentation and provision for continuous withdrawal of thick sludge are features of great importance.

Sewage treatment by chemical precipitation has been used in many localities, the reagents usually being lime or lime and copperas. The method entails a high operating expense, with slight prospects of recovery values, and cannot be said to possess attractive possibilities. The use of chlorine gas, however, for disinfection of the final clarified effluent is common practice and is satisfactory in meeting certain local conditions.

Treatment of Trade Waste

The field of industrial trade waste treatment is replete with possibilities which should attract the attention of chemical engineers. Broadly speaking, all methods of industrial waste water treatment are dependent on definite chemical reaction, or on the close delineation of physical chemical conditions. A number of unsuccessful trade waste treatment plants can be pointed out where the failure is directly traceable to the fact that an attempt was made to apply one of the standard methods of domestic sewage treatment to the problem, in contravention to basic chemical principles. The field belongs rightfully to chemical engineers, who can trace the offending elements in the waste waters back to their source and can regulate the other wastes or prescribe chemical additions to react with the offending elements or convert them into a physical state suitable for separation from the innocuous waters.

It would be difficult to describe standard methods of trade waste treatment because they will vary widely with local conditions at different plants even in the same industry. In general the following will apply:

(*a*) Sizable suspended solids—removed by screening or sedimentation.

(*b*) Colloidal solids—removed by addition of chemical coagulants and electrolytes, followed by sedimentation.

(*c*) Dissolved solids—removed by chemical precipitation, followed by sedimentation.

(*d*) Color, odor—removed by chemical precipitation, or sand filtration, etc.

Trade waste treatment naturally involves a constant overhead expense to the manufacturer without material gain except in cases where byproducts can be recovered. It is therefore essential that operating costs be reduced to a minimum, and this can be accomplished only by the careful study of the chemistry of the plant itself with a view to bringing into use every potential coagulant which might otherwise be thrown away without utilization, and the regulation of the internal plant routine to make the waste water conditions as uniform as possible. It also means a careful survey of the pollution conditions to ascertain the minimum degree of purification which will suffice.

The mechanical methods of dosing waste waters, the design of adequate sedimentation units to produce uniform clarification and a minimum volume of sludge, the use of carefully determined chemicals where necessary, are all essential factors which tend to make the field of trade waste treatment a distinct profession, merging the experience of the chemical and sanitary engineers.

With the close of the war has come a renewed siege of anti-pollution campaigns on the part of the various health authorities. These campaigns are doubtless justified where an economical system of overcoming the pollution evil can be offered. All public-spirited citizens will welcome the restoration of our rivers and waterways to their original clean condition because they are the natural parks and playgrounds of the populace at large. If they can be cleaned up without placing an excessive burden on the industry, which also has a right to exist, all energies should be bent to that end.

It is apparent that the chemical engineer has a definite interest in matters pertaining to sewage and trade waste treatment, and it is to be hoped that this interest will soon manifest itself in distinct contributions to the art as now practiced.

New York City.

Purification of Sewage With Activated Sludge

Activated sludge has the property of purifying raw sewage in the presence of air and it is generally admitted that this remarkable purifying action is exercised according to the mechanism of nitric fermentation. R. Cambier has studied this subject and presented the results of his work before the French Academy of Sciences (*Comptes rendus*, March 15, 1920, pp. 681-684). He subjected raw sewage in the presence of activated sludge to forced aëration at temperatures between 0 and 55 deg. C. and found that the most appropriate working temperature is between 20 and 25 deg. C., that the presence of nitrous acid is not appreciably manifested below 30 deg. C. and that activated sludges are capable of transforming nitrites into nitrates at ordinary temperature. If a mixture of activated sludge and sewage after nitrification is left to settle for three hours and the supernatant clarified liquid decanted, the liquid separated from the centrifuged residue is found to be poor in nitrates but containing 10 mg. of ammonia per liter and that the nitrifying capacity of the sludge is not altered.

Putting the Vegetable Oil Industry on a Scientific Basis

An Outline of the Vegetable Oil and Fat Industry in Which Attention Is Directed to Problems Connected With the Production of Crude Oils and Fats, Laboratory and Refining Problems, and Research Opportunities in Manufactured Products

BY HERBERT S. BAILEY*

UNTIL comparatively recent times we have been accustomed to look upon certain fats and oils as suitable only for technical purposes, while others were classed as edible. This distinction was to a certain extent geographical. The Russians, for instance, used linseed and sunflower seed oils for food, while in England and America these were of importance only in the paint and allied industries. The Eskimo dines daily on whale blubber and the African soaks his food in palm oil, but in the countries of the temperate zone whale oil has been associated with insecticidal sprays, and palm oil with tinplate manufacture.

With the recent developments in the art of refining, deodorizing and hydrogenating, these sharp lines of demarkation between edible and technical oils have largely disappeared. There are of course a few oils, such as castor, which are still taboo in civilized kitchens, and the sad lesson which Germany learned just before the war, when the poisonous hydnocarpus oil or Marotti fat was used in margarines, has made us hesitant about using new products in foods. Hydrogenated whale oil is today a regular constituent of some of the Continental butter substitutes and the writer has seen samples of fish oils which were as sweet and palatable as any of the commonly accepted edible vegetable oils.

The fact that nearly all fats and oils can be made edible does not mean, however, that they are now or will be in the near future employed promiscuously in food products. There are at least three basic reasons why some oils will remain in the technical group. One of these is psychological, one chemical and the third economic.

In the edible oil trade the conservatism of the non-scientific men at least is marked and it is more difficult to bring about a change in raw material even than in plant practice. Naturally, also, few manufacturers of food products care to risk the effect of the prejudice which would appear toward their goods if it were known that they were putting fish oil or horse tallow into their wares.

Because of their peculiar chemical composition, oils with good drying properties, like linseed, perilla and tung, are naturally more valuable to the paint maker than the lard substitute producer. Similarly the medicinal oils, such as cod liver, chaulmoorgra and castor, will be used largely by physicians, but because of the comparatively small demand of this trade, where the production is large the excess will go into technical lines.

Economically it is not profitable to subject some oils to the high refining necessary to convert them into satisfactory food products. Until the relative values of the fats and oils classed as technical and those at present used as food change, there is little prospect of any radical departure from the present grouping.

There was during the recent apparent shortage of oils a considerable volume of interesting and more or less valuable research on the utilization of well-known oils for new purposes and of little-known materials as sources of new oils. In these reconstruction days, however, the most fertile field of investigation is in improving the old or devising better new methods for the treatment of our common oils for the purposes for which they are already used. This will be especially true of oils such as soya bean and whale, which are on the border line between the technical and food groups, not quite the equal of linseed for paints or of cottonseed for lard substitutes.

The Scope of the Fat and Oil Industry

The various divisions of the fat and oil industry are so numerous that no single research laboratory, much less an individual investigator, can hope to cover them all. Dividing the field along the lines of the successive steps followed in obtaining the finished products from the raw oleaginous materials, we may start with the four main divisions:

A. Methods for obtaining crude oils from raw materials.

B. Subsequent treatment of the crude products.

C. The manufacture of derived products.

D. The utilization of byproducts.

Under the first of these headings will fall the various procedures for separating oil or fat from substances in which they occur in nature. At present there are but three methods of any consequence: Boiling out with steam; pressing out with hydraulic or tortional pressure; extraction with volatile solvents.

Refining Operations

Having obtained the crude oils, it is necessary to subject them to one or more of the following treatments before they are suitable for human consumption:

1. Washing, filtering or settling, as applied to the virgin oils such as olive and peanut.
2. Refining with an alkali or acid.
3. Bleaching with an absorptive material such as fullers earth or carbons, or by chemical agents.
4. Deodorizing.

Technical oils usually require some sort of purification before they go into the finished products; thus, for paint and varnish making, linseed oil is settled or filtered to remove the mucilagenous materials, and bleached if intended for especially light colored products.

Derived Products

Under the head of derived products might properly be discussed research related to the manufacture of boiled and bodied oils; lubricating greases, soaps, linoleum, rubber substitutes, stuffing grease; leather dressings, patent and artificial leathers, and many other lines in which fats and oils are used. Of perhaps more

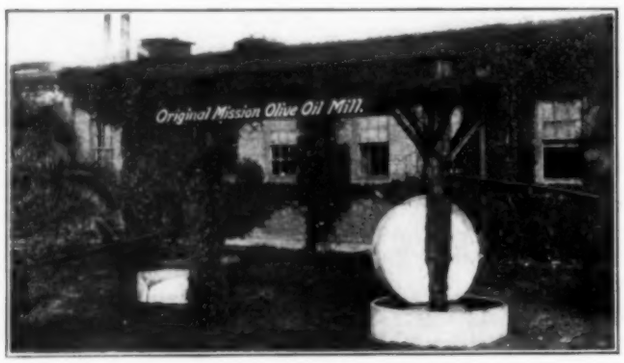
* Editor, Chemists' Section, *Cotton Oil Press.*

general interest are the manufactured food products, lard and butter substitutes and the so-called synthetic milks. In these industries there are various steps between the crude materials and the finished articles of commerce, but only a few of the more obvious research problems in this field will be suggested in this article.

Problems Connected With the Production of Crude Oils and Fats

Steam or Water Extraction

One of the primitive methods of obtaining oil is that of merely boiling the oleaginous raw material with water. This process is still used by the natives of the tropics in making their "chow" oil from the fleshy portion of the palm fruit. A modern adaptation of this process is found in our packing houses, where the fats are removed from animal tissues by steaming in tanks under pressure. That there is a possibility of increas-



A PRIMITIVE OLIVE OIL MILL

ing the efficiency of the present practice or improving the quality of the resulting fats is doubtless true, but these problems after comparatively little preliminary laboratory work would best be handled in the plant.

Extraction With Pressure

By far the larger part of our vegetable oils and a proportion of the animal fats are obtained by pressing, usually hot, the finely ground seeds or tissues containing them. The opportunities for the research chemist in this field are more limited than for the oil technologist who has mechanical genius, nevertheless there is still room for the chemical laboratory to be of great assistance to the crude oil mill. The time is coming when oil seeds will be purchased on the basis of their oil and food value, and the lucky chemist who devises a simple, rapid and yet reliable method for determining the oil content of the crude mill grist will win for himself a place beside Babcock, who did so much for the dairy industry. That a chemical treatment of some of the oil seeds may materially facilitate the pressing of the oil from them is probable—in fact, one such process has already been patented. Another problem for the laboratory is the process of fixing or, better, destroying the color bodies in the meals before they are pressed, thereby reducing materially the subsequent losses which now occur in the refining process.

Extraction With Volatile Solvent

It is in the extraction of oils and fats by means of volatile solvents that we find some of the most promising problems for the research chemist and oil technologist. While much work on extraction processes and suitable solvents has already been done, it is surprising how little reliable information is available in the literature. The chief objections to extraction systems at the present time are: The commonly supposed fire hazard, accompanied as it is by increased insurance rates; the loss of solvent in its removal from the oil and percolator residue; and the character of the products obtained.

To decrease the fire risk, it has been proposed to use di- or tri-chlorethylene, chloroform, or other non-flammable solvents, and there is still opportunity for investigators to find extraction liquids which will have all the advantages of benzene and gasoline without their disadvantages.

Research Must Be Carried to Semi-Commercial Stage

The points which must be borne in mind in such research are not only the power of the solvent to extract the fat or oil but the ease with which the solvent can be completely eliminated from the extract and spent meal and, what is often overlooked, the quality of the extract. Some solvents which in the laboratory in glass vessels have appeared very promising, when used in iron percolators on a large scale have been most disappointing. The meal in the plant equipment either packed so that it would not percolate or if extracted in tanks provided with agitators could not be properly mixed with the solvent. Again in some instances the meal, which on an experimental scale worked beautifully, when treated in 10-ton lots extracted so slowly or held the solvent so tenaciously that the operating department turned down the whole extraction proposition and "cussed" out the research laboratory as a lot of academic theorists.

One may obtain an oil—from cottonseed for instance—with some solvents, in glass flasks, which refines and bleaches with entire satisfaction, but the "stuff" turned out on a plant scale by an apparently identical procedure either will not refine at all or the losses more than counterbalance any advantages to be gained by extraction instead of pressing. These past failures, however, should not discourage further research but rather stimulate it and be a warning to those in charge of such investigation to fully test their discoveries on a semi-works scale before risking them in a full commercial trial. We shall have more to say about this point later.

Does Oil Extraction Differ From Inorganic Leaching?

A fundamental knowledge of the process of extraction is highly desirable at the present time. The commonly accepted view seems to be that there is a radical difference between leaching out an oil from the more or less completely ruptured tissues in which it occurs and the washing of an inorganic precipitate free from a soluble salt. Is this actually the case or do the same laws which have been found applicable to the inorganic leaching processes hold equally in the extraction of plant and animal constituents with solvents? This is a basic problem and one which might well be given serious study by some of the research laboratories of our universities. If we knew how to calculate the optimum conditions of pressure, temperature, size of particles and extent of draining in each percolation, from the solubility of the pure oil in the solvent at different temperatures and pressures, much of the present cut-and-try so-called research on this problem could be relegated to the "tank house."

Laboratory and Refining Problems

In a broad sense the term refining may be used to cover all those processes for the removal of free fatty acid, color, odor and other objectionable qualities from crude oils usually under the supervision of the refinery superintendent. Here we are dealing largely with strictly chemical or physical processes, therefore in this branch of the fat and oil industry the laboratory finds a most fertile field for research. The application of scientific knowledge to oil-refining is now woefully small, but the bearing which recent discoveries in the realms of colloids and catalyzers has to the operations is realized by many of our chemists and we may confidently expect some most important applications of this knowledge in the near future.

Refining Processes

Taking up the various refining processes, we find, first, the washing and clarifying of those glycerides which nature has given to us in a condition for use without chemical treatment. Aside from the biochemical problems of keeping the fat- or oil-bearing tissues sweet and free from any decomposition so that their products will be neutral and devoid of objectionable odors, there is little obvious opportunity here for investigations of a scientific character. However, in the preservation of such perishable materials as copra and fish refuse, which are usually allowed to decompose partly before being pressed, there is a chance for some valuable research work. That coconut oil can be made from properly prepared copra or even the fresh undried fruit so sweet and palatable that it requires no subsequent treatment has already been demonstrated. The cod liver oil obtained from sound livers is also said to be superior to any of the so-called refined oils, and doubtless in the pressing of olive oil, the premier of virgin oils, there is some opportunity for scientific study.

Oil refining in the restricted sense—the removal of free fatty acids and some color by treatment with chemicals—is doubtless receiving more attention from the research organizations of the industry than any other single phase of their activities. This is due partly to the realization by the refinery of their inability to obtain even under apparently identical conditions the same results with any two batches of oil in the plant kettles. Also the knowledge that about half the loss in refining is the result of saponification and occlusion of neutral oil makes it desirable to find as quickly as possible means for overcoming these difficulties.

Decolorizing and Neutralizing

With most crude oils the refining process has a twofold object, the neutralization of the free fatty acid and the removal of a part of the coloring matter. To accomplish this, alkali, usually caustic soda solution, is mixed with the crude and the soap thus formed is separated from the refined oil. There are many individual phases of the process which will bear considerable further investigation, but they are all comprehended in the study of the interrelation of temperature, strength of refining alkali and excess of alkali over that needed to neutralize the free fatty acids. The separate factors have all been studied many times both in the works laboratories and the refineries, but apparently we are still a long way from having any definite conception of the fundamental chemical and physical principles underlying the entire process. Probably the colloid chemist can best solve these problems, as at least a part of the coloring matter is a colloidal suspension in the oil, and obviously where it is a question of separation of soap from occluded oil a knowledge of the behavior of colloids will be very helpful.

Another angle from which to attack the refining problem is a search for reagents which will destroy or remove the color of the crude oil without injuring it. Perhaps more important is the neutralization of fatty acids without saponifying the neutral oil. We know that boric acid will coagulate some of the color bodies of crude cottonseed oil and that carbonates do not saponify glycerides as easily as caustic alkalis, but so far no one has devised or at least not divulged a commercially practical scheme for taking advantage of these facts.

Bleaching With Fullers Earth and Chars

Passing on to the next refining operation, that of bleaching, which is now usually effected in the edible oil trade by means of fullers earth, and in the paint and varnish business by merely heating or by subjecting the oil to the action of the ultra-violet light, we find another most promising field for investigation. The work of the Chemical Warfare Service on carbons for gas masks has stimulated the search for a char which would be so superior to fullers earth that it would pay to use it even if it were more expensive. Unfortunately some of the work on bleaching chars has been undertaken without a full realization of the fact that their action is specific. Investigators have taken carbons which were found especially valuable for gas masks and been surprised when they proved useless for the bleaching of oils. Some manufacturers of carbons do not hesitate to recommend their wares for removing the color from soya bean oil because they have proved satisfactory in bleaching glycerine or sugar house products. It is not at all unlikely that the selective decolorizing effect of carbon may be so specific that different oils will require different chars for the best results. Since many of the common oils contain more than one chromogenic body, in some instances a mixture of different carbons and fullers earths may bleach better than any single material. So far we have little scientific basis for any workable theory of the bleaching effect of absorptive materials. It is simply a question of trying out on each oil as many chars or earths as are available. Such tests, of course, should be made under different conditions of temperature and time and the loss of oil due to absorption determined in each experiment. Research of this type, however, while sometimes of more monetary value, will never deserve the recognition due to that which has for its ultimate goal the determination of the laws which underlie these processes.

Causes of Objectionable Odors and Flavors Unknown

The last step in the making of edible oils is the removal of objectionable odors and flavors by deodorization. This is in principle simply steam distillation of those substances which impart to the oil a disagreeable or too pronounced flavor. We say those substances which give the oil flavor, because we know practically nothing about what they are, or whether they exist at all in the oil as it occurs in nature. Whether there are many or few organoleptic bodies in a single oil and whether any of these are common to a number of oils is still a mystery. In fact, all we do know is

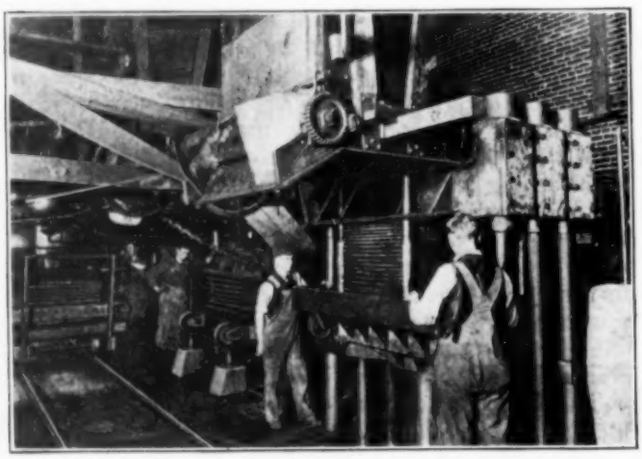
that if an oil is blown under vacuum with superheated steam, free acids, if present, and other substances, some of which give an aldehyde reaction, are carried off and the remaining oil is nearly tasteless and odorless. The practical results of the process are very satisfactory, except that in time the objectionable flavor may return, and in some instances steamed oils are more "tender"—that is, spoil more readily—than those which have not been so treated. It would seem that while there is undoubtedly opportunity to discover new and improve old deodorizing methods, the most interesting problem here is the identification of the flavors of the common vegetable oils.

Clarifying Technical Oils

The technical oils as a rule require some clarification and often bleaching before they are suitable for use. In the paint and varnish trade the principal oil, linseed, is usually "tanked" for a time to allow the separation of the albuminous matter. Attempts, some of them quite successful, have been made to hasten the process by the use of centrifugal separators or special heat treatments. Since this mucilagenous matter is in a very finely divided if not actually colloidal state, it is probable that the colloid chemist can help materially in finding means of expeditiously coagulating and getting rid of it. At any rate there is a real problem here that is deserving of someone's attention. The man who tackles this research will deserve the gratitude of the paint chemist if while he is devising means for removing this so-called "foots" he will find out what it is and why even a very small amount of it will ruin paint.

Bleaching Technical Oils

To obtain a light-colored linseed oil, it is often merely necessary to heat it to the proper temperature and a similar change takes place with many soya bean oils,



MODERN OLIVE OIL PLANT
Left, filling cloths. Center, forming cheeses. Right, pressing cakes.

but every little while one meets with an oil which does not respond to the heat treatment. What is it that causes this difference between two samples which so far as the chemist can tell by his analysis are identical? Also is there any simple method to remove the color substance, apparently present in some oils and not in others, that darkens instead of bleaches when heated?

At one time sunlight was used by at least one of our large American castor oil producers to bleach his off-colored oils, and of course this is still common practice with yellow palm oil and many waxes. Recently the ultra-violet light has been suggested and we are informed is actually used on a commercial scale for bleaching linseed oil. That its use may be extended to other oils is possible and of sufficient promise to warrant considerable research.

Chemical bleaches, such as acid bichromate, have been successfully employed with technical and even food oils, and there is no reason to believe that other reagents not yet studied might not be considerably more satisfactory than any of the present processes.

Research Connected With Manufactured Products

Action of Driers

During the recent high prices for linseed oil the possibility of using cheaper substitutes received considerable attention. This led to a greater interest in the semi-drying oils and driers in general. Important advances have been made in the last decade in the use of driers and some valuable scientific work has been done on the chemical reactions taking place during the drying of oils, but the question of how and why some metallic salts make an oil in which they have been dissolved dry to an elastic film has not yet been fully answered. There is a generally accepted belief among paint and varnish makers that a mixture of manganese and lead driers is better for linseed paints than either one alone. We also know that with soya bean oil cobalt salts give better results than lead and manganese. There are, however, several metals—for instance, vanadium and titanium—which have not yet been properly investigated.

A still more interesting set of problems in the field of driers leads into the study of optimum conditions under which to add the metallic salts to the oils. It is generally believed that it is the metal irrespective of the acid radical with which it is coupled that causes the oil to take on oxygen, but many paint and varnish makers still persist in using the difficult soluble substances, such as "shot manganese," instead of the acetate or fatty acid soaps. Apparently the temperature at which the drier is added to the oil and especially the heating or blowing the oil has received preceding the addition of the drier affects the quality of the finished boiled oil. Under some conditions the oil will dry with satisfactory speed but to a tender, cheesy film, and much is still to be learned about all these points. This rather superficial discussion of the drying oil problem will, it is hoped, suggest some lines of research which may lead to interesting and valuable studies.

China-Wood Oil

Tung or china-wood oil, that freak among drying oils, is of itself worthy of further investigation, although already much has been learned about its behavior toward heat and driers. The varnish maker knows that he must heat this oil just as near the jelling point as possible, to make it blend properly in the varnish, but he has no means, except the rule-of-thumb "string catching" of it to tell when this point has been reached. There are two possible ways in which the research laboratory can save him many gallons of jellied or undercooked oil, one by giving him definite directions as to how long and at what temperature he should heat each lot, and the other by discovering some process by which tung oil can be properly polymerized without the danger of setting it into an insoluble jell. This latter

is much the more promising, as there is such a difference in the behavior of different lots of tung oil that there is little chance of controlling the boiling process better than it is at present by the knowledge of a skilled varnish maker.

Polymerization by Blowing and Heating

Blown and heavy bodied oils are, it is supposed, polmerized gylcerides, but they are usually made by blowing the raw or refined oils with air at a more or less elevated temperature. That many oils can be polymerized by heating them out of contact with any appreciable amount of oxygen has been proved by carrying on the operation in nearly full sealed tubes. It is also known that by a combination of heating and blowing simultaneously or successively at different temperatures a great variety of products can be obtained from the same oil, but very little study has been given to the chemistry of these processes.

Rubber Substitutes—Lubricating Greases

By two or three American manufacturers of rubber substitutes much valuable research has been done on the vulcanizing as well as on the polymerization of oils, and the quality of some of their products would indicate that with just a little more study products of great commercial value in the rubber trade might be produced.

Recent work on the relation of colloids and jells to lubricating greases and soap has opened up a splendid field for a number of investigations, many of which will have a direct application to these industries. In England last year the "germ theory" of lubrication was brought out, and while some of the articles on it sound a bit more commercial than scientific, the fact that fatty acids have a surprising effect on the interfacial tension between mineral oils and aqueous solutions makes the "theory" worthy of further study. If glycerides or fatty acids can be proved to impart to mineral oils valuable lubricating properties which they alone do not possess, the demand for castor, rape and lard oils, and horse and other tallows in lubricants may be materially increased.

Artificial and Patent Leather—Lard Compounds

In the artificial and patent leather factories and, in fact, wherever nitrocellulose solutions are used or blown oil coatings are applied to flexible backings one will not have to search far to find both practical and theoretical research problems. In these fields again the materials with which we are dealing are probably in a colloidal condition, and a working knowledge of this phase of chemistry will be of great assistance to the investigator.

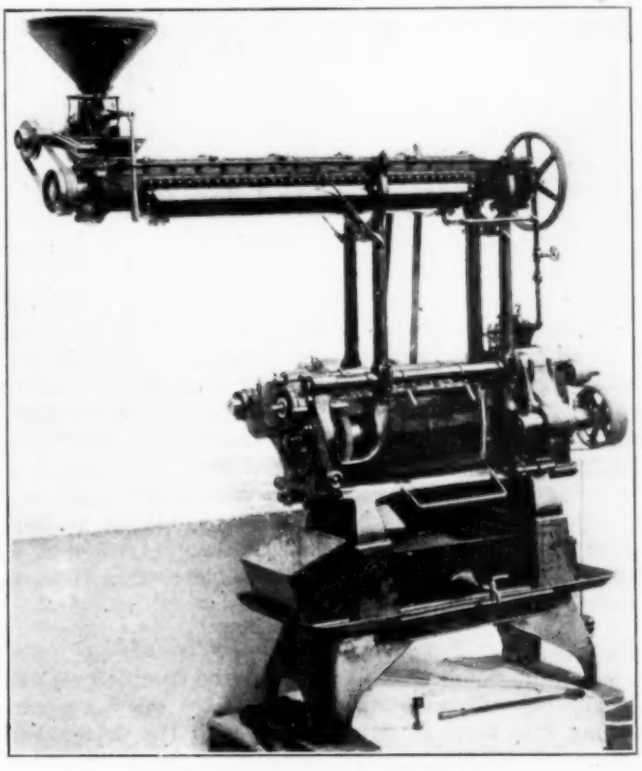
Turning now from the technical field to human foods, we come first to the production of lard substitutes. This industry consumes today in the United States just about half of the total vegetable oil produced in the country. Obviously, therefore, improved methods for decreasing the cost of manufacture or improving the quality of lard substitutes are of vital importance.

The processes for making lard substitutes, or "compounds" as they are commonly called, have reached a high degree of perfection and many of the brands on the market are at least equal if not superior to hog lard, but there is still plenty of opportunity for high-class research in this branch of the industry. The use of hardened vegetable oils in compounds is now common practice and food chemists would be disappointed if they did not find at about this point in the discussion mention of hydrogenation.

Although this process of making hard fats from liquid oils has been a favorite hunting ground for chemists and patent lawyers in recent years, none of the present processes is perfect, except on the patent side perhaps. The complete removal of the catalyzer, metallic or colloidal nickel, from the hardened oil is troublesome at times, and it is doubtful if more than a few of the hydrogenators know how to get the maximum hardening effect with the minimum expenditure of time, heat and labor. It is also within the realm of possibility that a catalyst cheaper and better than any of those at present in use will be discovered.

To many manufacturers the phase "continuous process" has a very pleasant sound, and if a really satisfactory continuous hardening process is perfected to replace the present batch processes, chemists will undoubtedly share the honors with the mechanical engineers. In addition to the conversion of the unsaturated glycerides into hard saturated ones, there is every reason to believe that with the proper choice of a catalyzer and operating conditions it will be practical to transform the flavor and color bodies of some oils into unobjectionable substances.

Aside from the flavor in compounds, which depends on the fats and oils used in making them, the most important qualities are color and consistency. The exact determination of these characteristics is at present impossible, and an interesting piece of research is to be found in devising methods for evaluating these properties. Of more immediate monetary value would be a method for predetermining from an analysis of the components used in making a batch of lard substitutes the color and especially the melting point of the finished product. Since the snowy whiteness and to a large extent the creamy consistency of the compound as marketed is the result of whipping air into the chilled



A SEMI-WORKS OIL EXPELLER

mixture of fats, it is of interest to know what effect, if any, this air has on the keeping qualities. One of the very common objections to lard substitutes is their tendency to become streaky or opalescent in spots. This is commonly ascribed to improper closing of the package and apparently is connected in some way with the gradual escape of the incorporated air. When once melted and allowed to cool again slowly, compounds usually separate into a mush, of crystals and more or less liquid oleans. Hog lard under ordinary kitchen conditions does not do this, and these facts offer a starting point for an investigation which would have as its objective a lard substitute with all of the desirable properties of true lard and without any of its undesirable ones.

Butter Substitutes

In the butter substitute factories the opportunities for research are even more promising than in the compound plants, as flavor and physical consistency are there of greater importance. So far margarines, especially those containing only vegetable fats, do not withstand satisfactorily changes in temperature, and it is necessary for the makers to change their formulæ to correspond with the climate in which their products are to be marketed. Butter has a long melting range in comparison with margarines, or, to say the same thing in the cook's phraseology, butter, although soft enough to spread as it comes from the ice chest, does not run until it has been in the hot kitchen for some time, but margarines either become quickly a mass of soupy grease in the summer or when taken from the refrigerator are so brittle that they crumble when one attempts to cut them.

Like butter, the substitutes are mixtures of glycerides, ripened in milk and, after cooling below their melting points, worked to remove the excess of water. The margarine fats in distinction from those of butter must be chilled very quickly to get a homogeneous mixture which will not be granular or streaked in the prints. So far no one has discovered any method by which the fat and milk mixture can be so completely blended that margarine could be churned from the buttermilk as in butter making. It is not essential, of course, that the problem of producing a margarine with a long melting range be solved in this particular way, and it may very well be that some mixture of glycerides will be found, either by combining natural fats and oils or hydrogenating them, which will by the present process yield a slow melting product.

The biochemist has, in the margarine maker's laboratory, a great opportunity for research along the lines of still further improving the flavor of these foods, and especially in finding means, other than by the use of preservatives, for preventing the comparatively rapid spoiling of his products. As the population of this country increases, the difficulty of obtaining a plentiful supply of milk is becoming greater and the demand for a milk substitute more apparent. While perhaps this is not a problem for the oil chemist, still it is so closely related to the margarine industry that it seems worth while mentioning.

Problems in Soap Manufacture

Nothing has been said so far of the specific problems connected with soap making, and space will not permit going into these in any detail, even if the writer were competent to do so. The demand for South American tallow and similar hard fats by the soap manufacturers during the war, and the fact that many of them are users of large quantities of hydrogenated oils, are indicative of their need for a plentiful supply of raw materials which will make hard soaps. Another thing that causes the soap maker trouble is the keeping properties of his wares; white soaps have a great tendency to turn yellow or dry out and crack, thus becoming less attractive to the purchaser. The increase in the price of sugar makes desirable some substitute for this substance in transparent soaps, and in the bleaching and purifying of garbage grease and refuse fats there are still unsolved problems.

Organization of Research Laboratory

A few of the fundamentals of successful research may properly be mentioned in concluding this sketch of the numerous possibilities open to the scientific investigator in the fat and oil industry. The director of an industrial research laboratory should be a man with a broad knowledge of chemistry, but not necessarily a specialist in any one line. He should have a wide acquaintance among the leaders in his profession and know where to turn for specific information on any problem, and also to which college to go for a new man to handle a special line of work. He must be politic but by no means "spineless," so that when his laboratory has devised a process with real merit he can get for it a fair trial by the operating department.

His assistants may well be of two types—first class analysts and men with the research instinct. Many a costly plant experiment has been a failure because of slipshod analytical control work, often due to the all too common notion that it is a "routine job" to do careful chemical analyses and therefore beneath the dignity of a research man. Where the force of assistants is large enough it is well to have in the organization specialists in the different chemical fields of colloids, catalyzers, microchemistry and biochemistry.

In addition to the usual laboratory equipment and such special apparatus as may be needed by the specialists, somewhere between the "lab table" and the plant there should by all means be a "semi-works." This plant, which will necessarily change more or less with each problem, becomes the common meeting ground for the investigator and the operator. It may well be under the direct supervision of the director of the research, but the mechanical department should also be conversant with its equipment and the operating department be cordially invited to make use of its facilities. The large chemical industries have learned that processes worked out on the "gram, centimeter, second" system seldom function according to schedule when translated directly to the factory scale, and have invested thousands of dollars in their semi-works. It is absolutely necessary if a research laboratory is to make good in anything but strictly scientific fields that its discoveries and inventions be carried through the stage where they are perfected in regular plant type—but small-size—equipment. The individual experiments at this semi-works plant should be under the direction of the chemist who developed the laboratory process.

With such a personnel and equipment and the elimination of all petty jealousies between the research laboratory and the production department, a research laboratory will bring as large financial returns in the fat and oil industries as in any of the other fields where chemistry is involved.

Savannah, Ga.

More and Better Tools Wanted

A Plea for Reliable Tabulated Physical and Chemical Constants, Especially for Melting Points, Vapor Tensions, Specific Heats, Latent Heats of Fusion and Vaporization, Thermochemical Data, Thermal and Electrical Conductivities and Thermal Emissivity

By J. W. RICHARDS*

THERE are essentially three kinds of research: (1) Investigation of chemically pure materials, the purest obtainable, in order to determine their chemical and physical properties with the highest accuracy, as a basis for scientific study of the influence of impurities.

(2) Investigation of the materials of engineering practically available. These are rarely of the highest purity of singleness of composition, but are such as are available in industry for engineering and technical use. Their study seldom results in laying bare the laws of nature, because of the complexity of the material and the number and amount of the impurities present in the commercial material. Such study is, however, of the highest practical importance in giving the engineer and technologist necessary data to use in his practical work with the actual materials at his disposal.

(3) Use of the data obtained in (1) and (2), principally the latter, to achieve engineering and technical results—i.e., build structures and use materials for all possible purposes, to devise processes and in general to attain engineering and technical ends.

Need for a Compendium of Reliable Physical and Chemical Constants

The tools of the engineer and technologist are thus very largely the information gathered by researches (1) and (2). The repository of such information is the technical literature, particularly the tables of physical and chemical constants and handbooks of engineering data concerning properties of engineering materials. When we come to consider the present available data which may be classified under (1) and (2), the engineer who understands how to use such data and knows what he wants is continually confronted by great lack of information—in other words, the real engineer needs more and better tools of this kind with which to do his real engineering and technical work.

The writer is convinced, perhaps because of his greater activity in this field, that data of the class (1) are woefully deficient and fragmentary. The best compendium of such information is in the revised Landolt and Börnstein "Physikalische und Chemische Tabellen," revised up to 1912. This has been supplemented by the "Tables Annuelles des Constantes Physiques et Chimiques," of which three volumes have appeared to date and the fourth is in preparation. These, and similar books and tables, are collections of the most reliable data accumulated in the last century or more by industrious scientific men. The data are of all degrees of reliability and of all degrees of incompleteness in any particular line. The quickest way to get an idea of the state of matters is by discussing a few concrete examples.

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Most of the data of the melting points of thermal compounds are marked by inaccuracy of the instruments used in determinations. Pyrometers of an accuracy of, say, 1 per cent at 1,000 deg. C. are of very modern construction and use. Many of the data prior to 1900 are only approximate, and for temperatures above 1,500 deg. C. are still liable to considerable error. Not only that, but the materials worked with have frequently been impure instead of the highest obtainable purity, and results for this reason also have been erroneous. The melting points of many common compounds have not yet been determined. At the present time many of the data on melting points may be said to be fairly satisfactory, but many also need revision and improvement.

Boiling Points

As ordinarily understood by this term, boiling point under normal atmospheric pressure is intended. The proper conception, however, should be that of vapor tension, and the data investigated should be the vapor tensions of substances in the solid and liquid states at all temperatures; the usual boiling point is merely one point in the vapor tension curve. Now, technologists and engineers have occasion to use in many problems vapor tensions of compounds at different temperatures and within wide limits of temperature. An inspection of the best available tables will show very meager data published in comparison with what is wanted. One hundred times as much information as is now in print could be used by industrial chemists and technologists in their everyday work; I am afraid that continued absence of such information for so long engenders the unfortunate feeling among some practical men that such data can be dispensed with or are unattainable. They really are neither the one nor the other; we ought to have them.

Specific Heats

When we consider the immense amount of thermal work done, by combustion of fuel or use of electric energy, to heat materials to high and low temperatures, including keeping our buildings warm, etc., it is lamentable how many data concerning the quantity of heat required to bring materials up to any given temperature are so imperfectly known. Most of the specific heats given in tables were determined between ordinary temperatures and 100 deg. C., the boiling point of water, and were, therefore, true only for this range of temperature. A few substances have been investigated to higher temperatures, but these are exceptions and not the rule; many have not been investigated at all. The engineer is confronted with a woeful lack of data on specific heat of substances at moderate and high temperatures, also of specific heats of liquids and

gases. It would be making a liberal statement to say that the tables contain 10 per cent of the accurate information in this line which engineers and technologists could use.

Latent Heat of Fusion

Considering again the immense amount of materials which are melted in the world by use of fuel or electric energy, it is lamentable how little data tables contain concerning the energy required to convert substances from solid to liquid state. Even the latent heat of fusion of iron and steel is in doubt, the guesses at it varying from 33 to 60 units, yet we ought to have accurate figures of the latent heat of fusion of pure iron and pure mixtures of iron in varying quantities, such as steels and cast irons. Similar criticism could be made of other metals and compounds which are melted industrially by the millions of tons, and yet the exact heat necessary to melt them is undetermined.

Latent Heats of Vaporization at Varying Pressures

Immense quantities of water are evaporated in steam boilers, and the latent heat of vaporization of water is fairly accurately known. Immense quantities of other materials are also evaporated or vaporized in other ways than in boilers, such as being distilled or vaporized from high-temperature furnaces; in many of these cases the actual energy of vaporization involved is practically unknown. The books of tables contain some scattering data; the chances are nine out of ten that when they are consulted for latent heat of vaporization the datum desired is not in them. There is a sad lack of information in this line, not only of the latent heat of vaporization at normal boiling point, but still less concerning the latent heat of vaporization at higher or lower pressures. Yet all of these come into account in technical calculations and are tools which the technologist should have in order to do his work properly.

Thermochemical Data

While we are thankful for the many heats of formation and combination contained in thermochemical tables, yet the requirements of practical use call for very many more, which have not so far been determined. As an example, we know the heats of formation of about forty-two alloys—many, however, unconfirmed and of uncertain reliability. All the alloys classified as brass are represented in these data by only two determinations, neither of which is really within the limits of commercial practice. Heats of formation of the many important steel alloys are practically unknown; the same is true of ordinary ferro-alloys. The heats of combination of metallic oxides forming various industrial slags are only to be approximately guessed at; the actual values for practical use are unknown. The heats of combination of metallic sulphides to form mattes are not known in even a single instance. The heat of formation of the common material FeS_2 is undetermined. A whole corps of competent thermochemical experimenters could be busied for years on the data which are unknown and badly needed in this field.

Thermal Conductivities

The proper calculation of heat losses through furnace walls and in all other kinds of apparatus requires correct values for thermal conductivities for different materials at different temperatures. The literature contains a few such determinations, usually limited to low temperatures. For every one of such existing determinations there are a dozen unknown which are badly needed in thermal engineering.

Electrical Conductivities

The electrical conductivity has been determined for many metals and a few alloys at ordinary temperatures, and in a few cases up to 1,000 deg. C. There exist only a few determinations on these substances in the liquid state, and such data are of great use in electric-furnace calculations. Similarly for compounds of the metals, refractory materials used for furnace walls, fused salts, etc., existing data are meager and need to be largely increased.

Electric-furnace engineering will never reach a satisfactory basis until there are many more data at hand concerning electrical and thermal conductivities at high temperatures.

Thermal Emissivity

The property of materials to radiate heat at ordinary and at high temperatures has been determined accurately in only a very few cases. A systematic study in this field is sorely needed. The results would be of great value in calculating radiation losses from all sorts of furnaces, rate of cooling of materials in the air, applying corrections to the radiation pyrometer, and several other chemical and metallurgical problems. There is a splendid field for laboratory research on thermal emissivity.

Other Constants Needed by Chemical and Metallurgical Engineers

This article is already too long, and yet only a fraction of the different fields have been mentioned in which experimental work is pressingly needed, results of which would be put to immediate practical use by chemical and metallurgical engineers. To barely mention a few other lines, without further elaboration, we will cite:

Viscosity of liquids and melted materials of all kinds, such as metals, slags, mattes, glasses, enamels, fused salts, etc.; surface tensions of all sorts of liquids and substances in the melted state; mechanical properties of metals and alloys at all temperatures up to their melting points (tensile and compressive strengths, elastic limit, elongation, contraction of area, fatigue tests, hardness, etc.); mechanical properties of structural materials useful in furnace construction, especially compressive strength at high temperatures; capillary constants for molten substances; dielectric constants of solids and liquids, particularly at high temperatures; critical temperatures and pressures of metals and metallic compounds; coefficients of linear and cubical expansion, from lowest to highest temperatures, in solid and liquid state; solubility of gases in metals and other substances, particularly in melted metals at high temperatures; velocity or rate of ignition of combustibles at different temperatures; temperatures of decomposition of metallic compounds; decomposition pressures of compounds at different temperatures; reaction gas pressures from mixtures of metallic oxides and carbon at different temperatures, etc.

May an awakening soon come!

Metallurgical Laboratory,
Lehigh University.

Future Rubber Research

An Appeal for More and Improved Methods of Testing Rubber and Its Products as a Guide to Compounding—Need for Study of Fabric and Design of Products—Continuous Vulcanizing and Temperature Control Essential

By ANDREW H. KING

FOR some time rubber research has been almost entirely in the hands of the chemists. In some respects the progress has been very satisfactory. But since chemical specialists have predominated, the present status of the industry may be described as lopsided. There are now many pressing problems which are essentially of a physical or a mechanical nature. Without detracting in the least from the good work of the rubber chemists, the writer wishes to point out a few of these problems.

Rubber testing is beyond question in most serious need for scientific attention. The methods in vogue today were largely forced on the manufacturers of hose, belting and other mechanical goods by the consumers for their own protection. Naturally these methods were not devised for the scientific exploration of the properties of a compound, but only enough data were desired to show that one article corresponded in value to one previously furnished. It is to the everlasting disgrace of these manufacturers who when compelled to go one mile with the consumers refused to go with them the Biblical twain. However, since it was formerly so easy to jumble a number of materials together and produce sort of a grab-bag product just good enough to get by, this condition can be easily explained if not fully understood. The writer has seen old formulas for hose, tubes, etc., which contained as many as twenty different mineral fillers and half a dozen different rubbers.

Five years ago almost the only criterion for comparing the relative values of compounds was tensile strength. Ultimate elongation was considered, but usually as of secondary importance. Recently an attempt has been made to measure the residuum of plasticity present in all stocks. The Davies-North method of determining permanent set may not be the last word—undoubtedly is not—but it is at least a step in the right direction. This is the quality the old line compounder measured with his fingers because his testing machine would not show it to him.

Wiegand at St. Louis last April emphasized very strongly the importance of stress-strain curves. It has been recognized for years that Hook's law does not apply to rubber. The ratio of stress to strain is itself a variable. The area under the stress-strain curve may be measured with a planimeter and from it the energy expended in stretching the test piece may be calculated.

Wiegand obtains his stress-strain curves with a Scott machine and two observers. It is a rather expensive method, but there is no testing machine which will serve. For that matter, the makers of testing machines have been more energetic in selling their product than in developing it to fit the needs of the industry. For example:

(*a*) All American machines are built to apply load to the piece at a rate of 20 in. per minute. Now it happens that a constant rate of elongation is not nearly as desirable as uniform increment of load. Machines should be built to give so many pounds per sq.in. increment per minute.

(*b*) The charting devices on all American machines plot increased load against jaw separation, which because of slippage is variable and has no bearing on the properties of the stock. The design of a good charting device depends largely on getting the proper grips, which unfortunately do not exist today.

In Europe the Schopper machine, which requires ring test pieces, is in use. American factories have declined to use this machine because of the difficulties of obtaining proper test pieces and the fact that due to unequal inner and outer circumferences the stress is not applied evenly and consequently the piece fails by tearing. However, it seems to me that we have been straining at a gnat and swallowing a camel.

In the matter of hysteresis, which is of maximum importance, there is no machine available except the Schwartz. This is, however, too light for high tensile strength compounds and has not the proper grips for straight test pieces. It is also unsuitable because of the method of applying the load. It seems remarkable that no one has yet published a description of a good hysteresis machine. Hysteresis is probably a measure of internal friction, a property which is now giving the solid tire men some worry.

Hardness is another quality as yet not satisfactorily measured. Some of the difficulty is in the matter of definition, but one machine which purports to measure it by deformation has so much friction in its bearings, etc., as to render all results worthless.

For resistance to abrasion we are also without satisfactory methods of measurement. Only makeshift apparatus designed after the grindstone are available.

Resistance to repeated stretching and to tearing are also important. The makers of testing machines are not yet aware of it.

Then there is the question of an accelerated age test. There are no methods which are quite satisfactory. For that matter, how much do we know about the aging of rubber and rubber articles? For my part I am willing to admit that in many cases I have no idea what causes it or how to stop it, let alone how to measure it.

It is my firm conviction that if we can catalog and evaluate the properties of rubber the designing of compounds for special purposes will be rendered much easier and surer than it is today.

In order to understand these phenomena better optical or other methods which will show us exactly how the particles of filler are contained by the rubber and something as to the structure of the rubber itself are quite necessary. Schipple's volume increase with

elongation may be one way. Metallographic methods ought to be of great value.

One could go on indefinitely pointing out work that should be done, but since space is limited this must be taken up later.

Compounding

Compounding was once the mystic art of the rubber industry. It is becoming, and rightly so, much less secretive. Some day American rubber men will understand that our national reputation hinges on all American products being absolutely satisfactory. The ceramic industry, which was formerly in the same boat with rubber, realizes this fact and co-operation is the watchword now.

However, we cannot get very far with a study of compounding until the physicist gives us better and more accurate methods of testing. Also compounding experiments should not be carried on solely from the physical standpoint. The information regarding the change in coefficient of vulcanization must be obtained simultaneously. It is remarkable how few rubber companies keep an accurate check on free and combined sulphur in their compounds. The steel companies are forced to maintain large routine laboratories for sulphur, manganese, fixed and graphitic carbon, etc. Sulphur plays the same part in rubber as carbon does in steel, yet we are indifferent to its variation. This is in most cases due not to the compounder but to a stingy policy of the directors, who may be excellent men but are ignorant of the fundamental reaction of their industry.

North's paper on compounding ingredients which was read at St. Louis last April was a good beginning. Other rubber laboratories should contribute their bit and soon we would begin to have some valuable fundamental information which is lacking at present.

In accelerators I believe we have enough for the present. Let us thoroughly investigate the few which we now know to be of value before going into this subject much deeper.

Fabric

Cotton fabrics are employed throughout the rubber industry. Yet how much do we know about them? For example, fabric must be held in place by rivets of rubber which are forced between the threads. It is almost impossible to make rubber stick to cotton threads. Why?

The internal friction of the fabric in a tire generates a large amount of heat. How can this be cut down or eliminated? Cord tires heat up less, but even they are not entirely satisfactory in this respect.

There are any number of problems directly bearing on the rubber industry which are not being worked on, at least they have not been described.

Design

In matters of design we are not exactly in a sound position. In tires nothing essentially new has come out for a long time.

A question which has never been satisfactorily answered is that of the stresses in these articles. The writer is of the opinion that in general the tires, etc., just happened to be put together and no special study of the forces encountered was made. In other words, many tires, etc., are poorly designed and fail not because of the materials but because of the design.

The supply of gutta percha for ocean cable is diminishing rapidly. A substance which will replace it will be very acceptable.

The fiber sole is now in general use. They must be cheapened and a method for rendering them slightly porous must be worked out. Leather is decreasing in supply and not only soles of rubber but tops of rubber and fabric are needed.

Continuous Processes

There is still too much intermittent hand work in the rubber factories. Machines for hose- and tire-building are in use, but the steps are far from being continuous. There are many other instances. For example, hose, tires, etc., are vulcanized in large heaters with steam. When the proper time has expired the steam is blown off and the heater cooled so it can be opened. Just consider the quantity of heat absolutely wasted. With coal at $8 or more a ton this cannot go on. Continuous processes of vulcanizing must be worked out.

Temperature Control

Temperature control, because of the extensive use of organic accelerators, is very important. Unfortunately too many companies depend on poor thermometers, which are rarely if ever checked up. Presses are particularly bad because they do not as a rule give the same temperature between all decks. The temperatures of mills and calenders are still judged by hand. Surely instruments can be developed for their direct measurement.

The rate of heat flow through fabricated articles such as a dredging sleeve, a pneumatic truck tire or a solid tire is of maximum importance in designing the stocks which are to be used. Unless this is carefully studied the surface is likely to be overvulcanized while the center will be porous or undercured. Very few accurate scientific data are available on this subject.

Conclusion

The writer has not attempted to go into detail on any one phase of the problems mentioned above. But surely there are so many big problems to be attacked that laboratories not employing physicists should engage a good one at once.

It should be unnecessary to point out that the British rubber factories are getting together and have organized a strictly British Rubber Research Laboratory under the management of the well-informed and able Dr. Twiss. The war has taught them the advantages of co-operation. But has this lesson been learned by American firms? Their men have helped in the work of the Rubber Section of the American Chemical Society, but the "powers that be" in certain of the older firms are "agin it." The English have been slow in many respects in rubber, but if they really pull together we may expect some strenuous competition and should be organized accordingly.

Surely the jealousy and antipathy which defeated the plan for an extensive co-operative rubber library in Akron a few years ago must be effectively killed. Is it not possible that a study of the physics of rubber and of rubber products, a study which is so broad that no one firm can hope to handle it alone, may not be the basis for that co-operation which we all desire but from which so many are held back for fear the other fellow will not come through with what they want to know after they have answered his question?

The Future of Chemical and Engineering Research in the Pulp and Paper Industry

Prospectus on Pulp and Paper Research—Byproduct Possibilities and Reduction of Wastes—Less Liquor Dilution by More Efficient Washing—Fuel and and Power Costs Reduced by Use of Vacuum Drying and Better Designed Beaters

By JOHN STEVENS, 3d

IN THE past ten years chemical progress in the manufacture of paper, the processes of which are so often thought of as being of a purely mechanical nature, has been exceeded in no other industry and stands as a striking example of the value of chemical control and research when applied in an intelligent manner. In fact it was no more than six years ago that one of our largest paper corporations, operating seven mills, possessed as its chemical staff one graduate chemist assisted by a boy to conduct such routine tests as were at that time considered sufficient to maintain the highest degree of efficiency! Today this same manufacturer has a staff of fifty chemists and engineers in addition to a small army of laboratory assistants whose duties consist of testing not only everything that enters into a product but the condition of the product in its various stages of manufacture as well. There can be only one result of such a drastic change of policy—an unprecedented standardization of heretofore rule-of-thumb methods coupled with the development of new processes, revealed through chemical research, which have made great strides particularly toward an efficient recovery of valuable byproducts.

Chemical Control vs. Research

The work of the chemist in the paper industry has up to the present time, therefore, been concerned largely with the control of existing processes together with research in the byproduct field. It is now quite apparent, however, that there are an infinite number of problems which remain unsolved and upon which the chemist must bend his efforts in the future. The fact that they exist reflects in no way upon the ability of the paper chemist, as it should be realized that his time has been occupied largely by the control of present processes; with a few exceptions, he has not been able to carry on extensive research. Many of the larger manufacturers have maintained research laboratories in addition to those devoted primarily to process control, but such development has been comparatively recent and has not had the opportunity, due largely to the short lapse of time, to demonstrate fully the wisdom of such a step.

On the other hand, the results obtained at the Brown Company under the guidance of such men as Moore and Richter should certainly serve as conclusive evidence that research in the pulp and paper industry is of infinite value. The utilization of waste sulphite liquor and the recovery of various byproducts from the gases and liquors of the alkaline pulp processes have occupied a prominent position for some time and considerable research has been devoted to these problems.

In view of present circumstances in the paper industry, however, it appears that the chief concern of the research chemist and engineer in the future should be directed to the study of fibrous raw materials and how best to prepare them, in an economic way, to take the place of our rapidly vanishing timber resources, together with a study of possible improvements in existing processes.

Byproduct Possibilities and Wastes

The wastes incident to the conversion of wood into paper pulp are not confined wholly to the loss of nonfibrous constituents, which in the past have either gone into the sewer or been utilized for their fuel value, but a large part of these wastes are the result of careless cooking conditions and inefficient methods of handling the product. It is not at all uncommon to find a mill realizing a 38 per cent yield of pulp when a 43 per cent yield would surely result from slight variations in the cooking schedule; but what is even more distressing is to see fully ten tons of valuable pulp lost in the back waters for every one hundred tons of paper made. Such a state of affairs emphasizes the fact that the enormous demand for paper is not the only reason for the depletion of our forest reserves but that wasteful treatment of our paper-making materials within the mills themselves is partly responsible. Furthermore, a 10 per cent saving in pulp would be far more profitable to the manufacturer than the recovery of byproducts has proved to be up to the present time. Has not the time therefore arrived for those in charge of scientific development in the paper mills to regard the treatment of the fibrous raw material, both as to source and as to process of manufacture, as of equal importance with byproduct recovery?

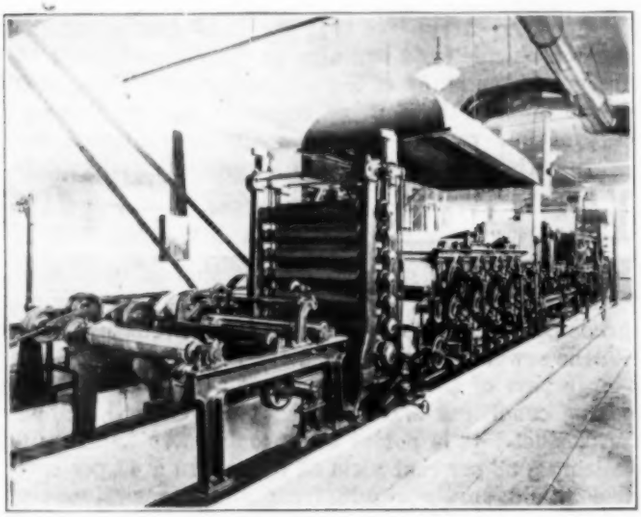
Reduction of Power Consumption

At this writing a great deal of promising research is being carried on in this and other fields and many of the most fundamental processes in paper manufacture are due for a rude jolt in the very near future. Much of this late development, such as the drying of paper continuously in a vacuum and improved methods of beating the pulp, is of largely mechanical nature, although none the less important, and will contribute as much as any chemical achievements to the advancement of the industry.

Furthermore, the processes of beating and drying are largely responsible for the enormous consumption of power in the paper mill and anything that can be done to save this valuable commodity is well worth the expenditure of considerable research. Take the matter of beating, for example; why should it be necessary to circulate pulp, say, 1,500 lb. to a beater load, for five

hours or more to effect the proper hydration for manufacture into papers requiring this quality, and in an apparatus which requires from 50 to 60 hp. throughout the operation? Surely there must be some simpler way, and an excellent opportunity is offered to the chemist, with his knowledge of the hydration of cellulose, to co-operate with the mechanical engineer in the design of more efficient equipment to effect this end.

Very similar to present beating practice is the manner in which pulp is ordinarily washed, particularly in the manufacture of high-grade papers. Here the half-stuff circulates around in washing engines of the same



EXPERIMENTAL 30-IN. COMBINATION CYLINDER AND FOURDRINIER PAPER MACHINE

general shape and design as the Hollander beater, except for the fact that the beater roll and bed-plate are supplanted by a paddlewheel to cause the motion of the stock. Fresh water is added continuously and the dirty water leaves at the same rate through the trunnions of several perforated washing drums that dip into the pulp.

More Efficient Washing

To those familiar with the methods of washing in other industries this practice must appear queer indeed. This is not at all surprising, as after all such an operation is virtually a dilution process and does not represent in any way the correct principle of displacement used in other industries. What the paper makers need in regard to washing is a method by which the dirty washings are successively removed from the pulp previous to their displacement by clean water. This method is, of course, used in pulp mills for the removal of bleach residues, but its application throughout the trade is still limited and is open for future development.

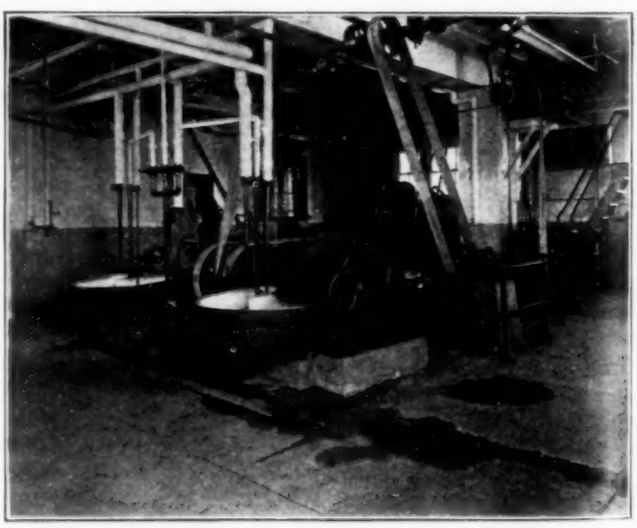
Vacuum Drying

The drying of paper is still another of the more or less mechanical processes in the paper mill which presents excellent possibilities for investigation. There are three main considerations in regard to the problem of drying—namely, the amount of steam used, the temperature of the steam, and the temperature difference between the steam and the paper. It is common knowledge that 50 per cent of the steam supplied to present drying systems is lost. This fact alone should warrant an extensive investigation of methods to improve this condition. It is also known that high temperatures are particularly injurious to the strength and quality of papers. This requires that in any improved process of drying the temperature of the steam must not be raised above that already found suitable.

We now come to the question of temperature difference, which governs largely the speed at which paper dries. The drying of paper in the atmosphere with steam at 5.3 lb. pressure within the driers will give a temperature difference of only sixteen degrees—that is, the difference between the temperature of the steam, 228 deg. F., and the temperature at which the water in the paper is boiled off, or 212 deg. F. Let us see what will happen if this same paper were dried in a vacuum of 28 in. of mercury using steam in the driers at the same pressure. The boiling point of water under a 28-in. vacuum is 100 deg. F., so the temperature difference is now 128 instead of 16. This means that the paper will be dried 128 ÷ 16, or 8 times as quickly under the vacuum as under atmospheric pressure and, furthermore, at a lower temperature. Therefore, one-eighth the number of driers in the ordinary atmospheric system would do the same amount of work and effect a considerable saving in steam at the same time, if placed under a 28-in. vacuum. Such a vacuum drying system is being developed and is an indication that the future may look to many revolutionary changes in paper drying.

Sulphate Process and New Pulp Materials

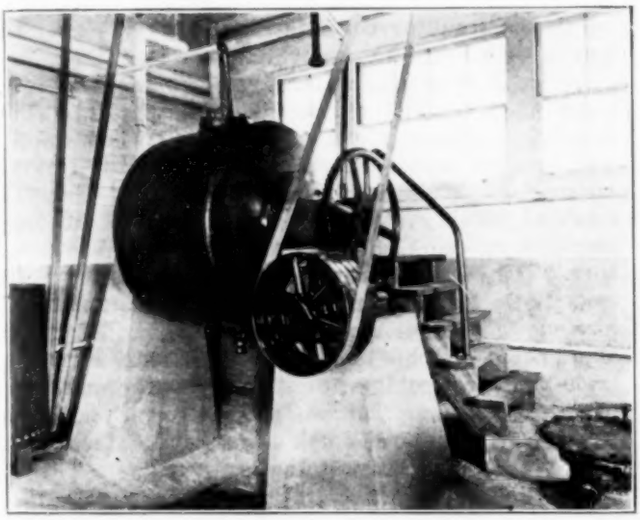
It is in regard to the utilization of fibrous materials, however, that chemical research can best be applied in the immediate future in the pulp and paper industry, and it is with this end in view that the few suggestions that appear here are written. It is when this point is reached that it becomes evident that the future of paper pulp manufacture centers largely around the so-called sulphate process. It so happens that practically all of the new materials now being introduced to the paper trade, such as waste cotton fiber, sugar cane, bamboo, etc., are best adapted to this process and open up at once a fertile field for research. Curiously enough, it has been found that bamboo, so treated, will yield a remarkably easy-bleaching pulp which is



BEATER EQUIPMENT USED FOR SEMI-COMMERCIAL EXPERIMENTS ON NEW FIBROUS RAW MATERIALS

tined to act as an excellent substitute for wood pulps used today.

There are, however, certain to be many problems incident to the introduction of these new materials into commercial practice and no small portion of them will be up to the pulp mill chemist to solve. Many of these fibrous materials do not contain enough ligneous matter to furnish adequate fuel for the burning of the liquors in the recovery process; others contain so much silica that the gelatinous silica compounds formed in contact with the alkaline liquors are bound to interfere with the settling and filtration of the lime sludge in the causticizing process.



EXPERIMENTAL ROTARY DIGESTER USED FOR THE SODA AND SULPHATE PULP PROCESS

These, and many other problems relative to the utilization of new raw materials, have heretofore received too little attention, which has resulted in the publication of many misleading statements. If all of the governing factors, both technical and economic, were carefully considered, it is doubtful whether more than 5 per cent of the materials proposed would be found suitable for paper manufacture. Too many investigators consider only the quality of the pulp and it never seems to occur to them that digester yield, liquor recovery and location of materials bear an equally important part. Nine times out of ten it has been found by experience that, although a material may produce a most satisfactory pulp, the yield per cu.ft. of digester space is only from one-third to one-half that of ordinary pulpwoods. This means that a four-digester soda mill would have to be turned into probably a ten-digester mill to obtain the same production from some of these new materials. It requires only simple calculation to reveal the fact that the effect on the annual investment return is quite discouraging.

In connection with the sulphate process itself, without the consideration of its application to new fibrous raw materials, there are many opportunities presented for improvement. A reliable, reasonably durable system of indirect cooking to prevent dilution of liquors is still to be found; there is room for engineering development on tumbling digester trunnion attachments and steam inlet arrangements to prevent leakage; an efficient method of washing the pulp to supplant diffuser systems and further prevent liquor dilution is desired; in the recovery end there is needed a good automatic feed for charging smelters; also chemical research looking toward a more valuable utilization of the various substances contained in the lignin dissolved in black liquors than using them for fuel and evaporating purposes; the disposal of lime sludge is an important problem which should be solved in the immediate future, as many of the mills are now contemplating this step.

Pulp From Southern Pine

The application of the sulphate process to many of our common pulpwoods such as the Southern pines should offer possibilities of improvement. It is doubtful, however, if it will ever be practicable to manufacture bleached pulps from extremely pitchy woods, such as the long leaf pine, by this process.

The content of resins in this pine is very high, when considering it as a pulpwood, but if looked at from the standpoint of the rosin and turpentine industry it is too low for economical operation. For example, the stumpwood used by the extraction plants often contains 24 per cent rosin, while the pulpwood seldom averages over 5 per cent. There have been attempts in late years to combine the extraction and pulping processes, but up to the present time this has not been successful on a commercial scale. The fact that the wood is prepared by a hog for extraction and that the extracting process removes most of the resins is ample explanation of the failure of previous attempts. Hogged wood cannot be used in the ordinary pulp digesters and black liquors in the sulphate process will not burn off if the resins which constitute a large part of the fuel value are first removed from the wood. It therefore appears that this problem has been attacked from the wrong angle and that there is room for valuable research.

In the first place, the proper sized chip must be determined which will "strike a happy medium" between the ideal hogged wood in the extraction process and the larger chips in the pulping process. It is certain, however, that either one or both of these processes will have to sacrifice something in order to obtain satisfactory operating conditions with a combination of the two. After the rosin and turpentine have been removed from the chips, the next logical step seems to be the application of a pulping process that does not require liquor recovery. We are therefore limited to the sulphite process and with certain variations in cooking conditions from the ordinary practice there is little doubt that a good quality bleachable pulp can be produced. Engineers and designers should also come forward and evolve an apparatus which will allow the extraction and pulping operations to be carried out in the same piece of equipment.

This and other problems as briefly reviewed in this paper emphasize the fact that the surface of chemical research in the paper industry has merely been scratched and that myriads of opportunities exist for future development. No doubt the foregoing review of some of the possibilities afforded may be characterized in the same way—there is so much yet to be done and so little mentioned. The conception of the idea is a very small part of the success of a project, however, so that what is now needed is the diligent solution of the many problems and not mere suggestions.

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Applied Colloid Chemistry

A Summarized Outline of the Present-Day Role of Colloid Chemistry as Applied to the Solution of Widely Diversified Theoretical and Practical Problems in Inorganic and Organic Industrial Chemistry

By WILDER D. BANCROFT

I HAVE stated elsewhere that a knowledge of colloid chemistry is essential to anybody who really wishes to understand about: cement, bricks, pottery, porcelain, glass, enamels; oils, greases, soaps, candles; glue, starch, and adhesives; paints, varnishes, lacquers; rubber, celluloid, and other plastics; leather, paper, textiles; casts, pencils, and crayons; inks; roads, foundry cores; coke, asphalt; graphites, patines, zinc, phosphorus, sodium, and aluminum; contact sulphuric acid, hardened oils, etc.; beer, ale, and wine; cream, butter, cheese, and casein products; cooking, washing, dyeing, printing; ore flotation, water purification, sewage disposal; smoke prevention; photography; wireless telegraphy; illuminants; comets; pharmacy; physiology.

What Colloid Chemistry Is

Since the connection of some of these with colloid chemistry may not be obvious to everybody I am going to run over some of the points which involve colloids. Since a phase is defined as colloidal when it is sufficiently finely divided, colloid chemistry may be called the chemistry of bubbles, drops, grains, filaments and films, because in each of these cases at least one dimension of the phase is very small. This is not a strictly scientific statement, because a bubble cannot exist without a film around it, and both filaments and films may be considered as composed of coalesced grains or drops. Jellies also present some difficulties because they are not obviously fibrous, and if we classify them as thick films we cannot say that one dimension is extremely small. These difficulties are inherent in any rather epigrammatic classification and are not serious.

Colloids in the Ceramics Industry

When clay is heated the grains sinter together and form bricks which are less porous the higher they are heated. Sintered refractories involve the same principle but different raw materials. When selected clays are used with addition of fluxing material we get the different forms of pottery. Porcelain is a modified silica glass made translucent by crystals of sillimanite, $Al_2O_3SiO_2$, and it has been suggested that some of the furnace losses in making porcelain might be cut down by using powdered sillimanite in the mix. If the heated mass fuses more or less completely and does not become entirely crystalline on cooling we get a glaze or a glass as the case may be. In the colored glasses and glazes the coloring matter is often colloidal, ruby glass being the stock example. A white enamel is a glaze made opaque by suspended particles of stannic oxide, calcium phosphate, zirconia, or something of that sort. Haber states that 3,000,000 kg. of stannic oxide was saved per year by adding the stannic oxide to the enamel in such a way as to cause less of it to be dissolved.

Cement owes its value to the power of the fine grains to gelatinize with water and set. Other things being equal, the resulting concrete is stronger the finer the grinding of the clinker. When the Lackawanna R.R. built its famous viaduct the specifications called for more finely ground clinker than most plants could furnish. In making plaster casts the time of setting and, to some extent, the grain size are modified by the addition of colloidal substances. Some of the good qualities of alloy steels are due in part to the other elements bringing about a more finely grained structure. The use of addition agents in electroplating and electrolytic refining involves the decrease in crystal size due to adsorption of the addition agent. The gelatine in photographic films gives us colloidal silver bromide and the ripening process changes the amount of adsorbed gelatine. The concomitant coarsening of the grains is purely incidental. One of the factors determining the capacity of the lead storage cell is the porosity of the grids. Experiments by Prof. Briggs of Cornell University make it probable that the effect of lithium hydroxide in the Edison cell is to produce suitable grain size and degree of porosity. The color and opacity of pigments vary with the size and structure of the grains. The possibility of adding a white filler like ground barytes to a red pigment without making the tint paler depends on the fact that fine powders tend to coat coarser ones. When writing with a pencil or crayon the surface to be written on must abrade the writing instrument and must hold the resulting powder in place.

The formation of coke involves the obtaining of a granular structure giving strength and porosity. The modern gas mask owes its efficiency chiefly to the adsorbing properties of porous charcoal. The catalytic action of pulverulent solids is the important factor in connection with contact sulphuric acid, Deacon chlorine, Haber ammonia, Ostwald nitric acid, Chance-Claus sulphur, Sabatier hydrogenation, dehydrogenation and dehydration, surface combustion, Welsbach mantles and many other things. The use of fullers earth depends on its adsorbing properties.

Suspended Colloidal Particles

The Cottrell process for removing fumes involves the electrical transference of suspended grains and drops. With such illuminants as candles, oil, gas and acetylene the light is due to incandescent carbonaceous particles. The tails of comets contain colloidal particles and their luminosity is apparently a large-scale occurrence of the Tyndall beam.

Enzymes and bacilli are in colloidal solution and consequently all fermentation processes involve colloid chemistry. The whole subject of toxins and antitoxins will undoubtedly have to be worked out as a problem

in adsorption. Most writing inks consist of suspended particles, as in the case of the carbon inks and the old-fashioned iron-tannin inks, or of solutions which oxidize on the paper, forming grains there. We know that soap forms colloidal solutions in water, and it is probable that the fats are in colloidal solution in many oils and other organic liquids. So-called solutions of rubber and of cellulose are always colloidal, and so are the cellulose nitrates when apparently dissolved in amyl acetate, acetone, or ether and alcohol.

Colloidal fuel is said to be less dangerous than straight fuel oil because it is denser than water and accidental fires can therefore be put out by water. Water purification is due in part to the carrying down of bacteria and suspended particles by gelatinous alumina, etc. The red coloring matter of grape juice and of the wine that is made from it is colloidal and can be filtered out by means of an ultra-filter. Cocoa is obviously a colloidal solution and both appearance and flavor vary markedly with the method of preparation. In coffee and tea the suspended particles cannot be seen by the naked eye, but they are there.

The so-called tannin solutions used in making leather are colloidal. Casein is in colloidal solution in milk and its precipitation is the first step in the manufacture of cheese. The asphalt from Trinidad contains finely divided siliceous matter suspended in it. When making sodium or aluminum electrolytically the temperature of the bath must be held as low as possible or there will be undue formation of the so-called metallic fog, with enormous decrease in current efficiency.

Emulsions

Milk is an emulsion of butter fat in water. Other well-known emulsions are mayonnaise, cod-liver oil and lanolin, this last being an emulsion of water in wool-fat. By adding water to a mineral oil containing a lime soap we get an emulsion of water in oil which is so stiff that it constitutes a grease. The stabilizing action of water on ready-mixed paints is due to the formation of an emulsion of water in oil with rosin as emulsifying agent. The rubber latex is an emulsion about which we have read, though few of us have seen it. The fact that rubber is in the form of liquid drops is accounted for by assuming that the rubber is depolymerized; but this explanation could scarcely be applied to milk, though the butter fat occurs as liquid drops.

In pharmacy the making of emulsions is an empirical art and it is only recently that the scientific side of the subject has been developed. Although Cottrell has done brilliant work on the converse problem of destroying emulsions, we must admit that as yet there has been no systematic study of this subject in spite of its importance in the oil industry.

The properties of emulsions are of tremendous importance in physiology, because they enable us to account for the antagonistic action of sodium and calcium salts and for a number of the properties of protoplasm. Emulsions are used in preparing foundry cores for baking and in the kerosene spray for trees, merely to mention two instances. The solid alcohol of commerce is a jelly and not a stiff emulsion.

Selective Wetting

Selective wetting is the underlying principle of the Elmore bulk oil flotation process, and it is no longer necessary to dry white lead before grinding it with oil, because linseed oil displaces water readily and completely from the pigment. The separation of finely ground coal from ash by means of oil is a special application of the Elmore process. The shower-proofing of fabrics is done by coating the fibers with a substance which is not wetted readily by water and the treated fabric then lets air through readily but stops rain, at least up to a certain point.

The Importance of Bubbles

Bubbles play an important part in making certain soaps float, in bread, and in giving the color to white flowers and white hair. The formation of foam on beer is due to the colloidal albumoses in the beer, which increase the viscosity of the films around the bubbles and consequently make the bubbles more permanent. In the case of champagne there is less colloidal material in suspension, the films around the bubbles are less viscous, and the foam is much less stable. For lecture experiments the law makes it necessary to substitute near-beer and ginger ale, but the principle remains the same.

The fighting of fire by the use of Foamite is an interesting application of bubbles. The method fails when applied to burning aluminum powder because the aluminum powder is carried up in the film and because aluminum will burn in carbon dioxide, reducing it to carbon monoxide. Ore flotation depends on the selective wetting of the ore by the oil and on the formation of bubbles. In the Minerals Separation process the films are very viscous and it is scarcely an exaggeration to speak of armor-plated bubbles. In the Callow process there are fewer particles in the surface films, which are consequently less viscous and the bubbles are therefore more fragile. It was recently stated that 60,000,000 tons of ore was treated by flotation process in 1918. Some experiments have been made on removing colloidal matter from sewage by a process similar to the Elmore bulk oil process; but this was not a success. It is quite possible that better results might be obtained by a modification of the bubble process.

Fibrous Colloids

Paper, textiles and leather are all fibrous colloids. The tanning of leather consists essentially in making one colloid insoluble by the addition of another, tannin or chromium oxide, in the vegetable and mineral tanning. Artificial silk is an important industry depending on the properties of filaments, and certainly no one can question the technical importance of the incandescent lamp. It is still something of a question whether soaps, jellies, celluloid, rubber, etc., have a fibrous structure and are to be considered as filaments, or whether they have a honeycomb structure and are to be considered as emulsions; but nobody will dispute their being colloids.

Colloids in Foodstuffs

Cooking of meat involves changes in a distinctly colloidal material; poaching or scrambling eggs depends on the coagulation of colloids. The amount of fat adsorbed by a doughnut is quite surprising. The staleness of bread is not necessarily due, as most people suppose, to an actual drying, but apparently involves a displacement of the water equilibrium between the starch and the gluten. Mashed potatoes are certainly colloidal, and the cooking of cereals is partly a problem in the swelling of colloids. In fondant we have grains

of sugar made plastic by surface films of a solution of partly inverted sugar. This suggests the possibility of making fondant without cooking by starting from confectioners' sugar and a glucose solution.

Adsorption Phenomena in Dyeing

The dyeing and printing of fabrics involve adsorption upon fibers. In calico printing the coloring matter is mixed with British gum or some other thickener to prevent its running. When a coloring matter will not dye cloth directly the dyeing can be done by mordanting the cloth, a mordant being a substance which adsorbs the dye and is adsorbed by the cloth. The metallic mordants are used chiefly for the acid dyes, while tannin is one of the most satisfactory mordants for the basic dyes. Owing to the ease with which tannin is peptized by water it is usual to fix the tannin on the cloth by means of tartar emetic.

Function of Soap in Washing

Washing is the removal of adsorbed material, usually by peptization. Soap is adsorbed readily by the dirt and removes the latter from the fabric or the flesh. Dry cleaning is peptization by organic liquids instead of by water. Ink may be removed from old newspapers by washing with soap, by treatment with sodium silicate, or by froth flotation. Rit is a series of dyes, made up apparently with some soap. It will dye fabrics, but does not stain the hands.

Adhesive Properties Due to Adsorbed Surface Films

The importance of glue and other adhesives is due to their forming films which are adsorbed strongly by the surfaces which are to be held together. It is because of the difference in adsorption that we have to use different adhesives with different substances. If the film remains liquid it will both hold the particles and make the mass plastic, as in the case of wet sand, of fondant, and of oiled roads. With more liquid we change from plastic flow to viscous flow. The oil requirement for pigments is apparently the amount necessary to give a certain degree of plastic flow. When water forces fine sand into the state of loose piling we have the conditions for quicksand.

Other Examples of Surface Films

A drying oil forms a surface film which may be used to hold the pigment grains firmly on the painted surface. Varnishes and lacquers are surface films intended to give increased permanency and beauty. The whole question of the manufacture of varnishes is one that should be turned over to the colloid chemist. It does not seem possible that the present purely empirical methods can be the best. Patines are films of salts adsorbed on metallic surfaces. The adsorbed oxide films on the surfaces of aluminum and nickel decrease the corrosion of these metals and make it possible for us to use them commercially. Passive iron owes its properties to the presence of an adsorbed film of a higher oxide. When condensing phosphorus or zinc vapors the important thing is to prevent the formation of films around the drops. That the structure of graphite is an important factor is shown by the greater apparent density of the natural graphite, which makes it better for use in crucibles. The electric-furnace graphite made at high temperatures is not so good for lubricating purposes as the more flaky and unctuous graphite obtained at somewhat lower temperatures.

The detectors and coherers used in wireless telegraphy appear to function, at least in part, because of adsorbed air films. Electrolytic reduction is due to monatomic hydrogen produced at the cathode and a high concentration of this substance is the cause of hydrogen overvoltage.

Cornell University.

Filtration of Colloids

Dr. W. R. Ormandy, who contributed a paper on "The Osmose Process for the Filtration of Colloids," at the July 13 meeting of the Society of Chemical Industry at Newcastle, said that the special method of treatment under consideration depended on the utilization of certain properties of finely divided particles in suspension. The new process for the application of physiochemical laws is in many respects so new that it is necessary to deal shortly with the underlying principles before the methods of their application and the limitations of the process can be properly understood.

Colloids can be divided into at least two groups, the reversible and the irreversible colloids. To the reversible group belong such substances as glue, gelatine which can be dissolved in water, dried and again dissolved in water without any great alteration in properties. To the irreversible group belong such substances as albumin, which after treatment with boiling water become absolutely insoluble. For the most part, however, the nature of the colloid is largely dependent upon the size of the particles. Sufficiently fine particles when suspended in water exhibit what is known as the Brownian movement, which is the more energetic the smaller the particle. This Brownian movement is now regarded as the visible symbol of molecular bombardment, as has been largely proved by the researches of Prof. Perrin. Generally speaking, particles of matter exceeding 0.0001 mm. in diameter will eventually settle from solution. This is about the limit of microscopic visibility. The fact that particles below the limiting size do not settle means that the molecular and electrical forces outweigh the action of gravitation. So far back as 1869 Jevons noticed that the intensity of the Brownian movement of clay particles was increased by the addition of traces of certain types of bodies and inhibited by the addition of other types of bodies. In 1895 Bliss noticed that a clay suspension exhibited increased Brownian movement with the addition of traces of alkali, but that the addition of further quantities again reduced the movement. It has long been known that the addition of certain types of chemicals tended to cause coagulation of colloids suspended in water; thus the addition of calcium hydrate and aluminum sulphate to bring about the settlement of sewage sludge is ancient history.

Dr. Ormandy took a suspension of ball china, to which had been added the necessary amount of electrolyte, and poured it into a copper cylinder having a carbon pole suspended in the center. On passing a current of about 60 volts through the liquid so that the central carbon pole was the anode, the clay was not only deposited very rapidly on the anode, but, although the clay was deposited under water, the clay on the anode was found to be remarkably dry. This result was due to the peculiar action by which water was repelled from the anode through a porous diaphragm, the action being known as electro-endosmosis. If, instead of using a stationary anode, a horizontal rotating anode was used, this process could be made continuous.—*Chemical Age* (London), July 17, 1920.

The Leather Industry

Many of the Problems Awaiting Solution in Such Phases of Leather Manufacture as Unhairing, Deliming, Bating, Tanning, Stuffing and Dyeing Involve Fundamental Scientific Principles Which Can Best Be Studied Through Co-operation Between University and Tannery Chemists

By JOHN ARTHUR WILSON*

IN THE hands of men thoroughly trained in modern chemistry, capable of original research, and provided with the facilities of a tannery, chemistry will probably eventually revolutionize the industry. But in the hands of less able men it is a source of danger that many a tanner has learned to his sorrow, with the result that even today a number of tanners either employ no chemist at all or else limit the work of those they do employ as chemists to mere analytical routine, and this in the face of the fact that the processes used in making leather are essentially chemical. The leather chemist has made considerable progress, but it has been small compared to what might have been expected from the progress of the pure science. Yet it is not difficult to see why greater results have not been achieved in the field of leather chemistry; the great majority of men who enter the tannery as chemists have an education no greater than that ordinarily required for the degree of bachelor of science, and this alone is entirely insufficient to cope with the real problems of the industry.

Industry Developed Through Empirical Evolution

The manufacture of leather is a most complex chemical industry and many of the processes in use today are the results of centuries of rule-of-thumb juggling. Along with the development of processes, accompanied as they often were by very costly failures, the practical tanner acquired an appreciation of the extreme danger of deviating very far from established practice. If he thought a process could be improved, he would first make only the slightest change and then wait weeks, perhaps months, to note any effect upon the finished leather. If no difference, or possibly a slight one for the better, could be detected, he would then institute a bigger change. Often it would be found that a small improvement in one process necessitated corresponding changes in several other processes. The young chemist usually fails to appreciate the need for this extreme caution and he is often ignorant of his ignorance of the fundamental chemical principles involved in making leather. When such a man is given free rein in the tannery, the results are much more likely to be fatal than profitable.

Study of Fundamental Principles Essential

The first applications of chemistry should be devoted to investigations of the molecular mechanism of present processes, the fundamental principles of which are not yet definitely known. Any increase in knowledge in this direction would permit the establishment of more satisfactory systems of control over the processes. In such investigations it is likely also that new principles would be discovered and these might form the basis for new and better processes. Because much of the necessary experimental work would require very refined apparatus and great skill in accurate measurements, it would seem that the best results would come from close co-operation between the industry and the university.

With little extra work and no sacrifice of any of the objects in view, the chemist of the university could make much of his research in pure chemistry of direct value to the industry if only he were aware of the industry's needs. Often a very elaborate and painstaking research would prove of the greatest value to leather chemistry if a few additional data had been obtained, which would have been easy enough with the apparatus set up and the work in full swing, but which would present formidable difficulties to the tannery chemist without suitable equipment. It would undoubtedly prove very profitable for the industry to finance research on a large scale at the university, and all results of such work should be published freely to be of greatest good. While the work would be primarily concerned with the chemistry of leather manufacture, it will be seen from the problems now to be outlined that the field is so broad that the gain to pure science would probably be fully as great as that to the industry.

Soaking the Hides

Hides are received at the tannery in any of four different conditions: fresh, salted and wet, salted and dried, and dried without salting. The first of the chief operations is "soaking," which consists in putting the hides into vats of water and changing the water frequently until the hides are clean and have reached equilibrium with the water; usually several days are required. Dried hides absorb water very slowly, but they must remain in the soak vats until they have acquired their normal amount of water or the leather later on will not have the proper suppleness. The process of imbibition is sometimes hastened by adding alkalis to the soak water.

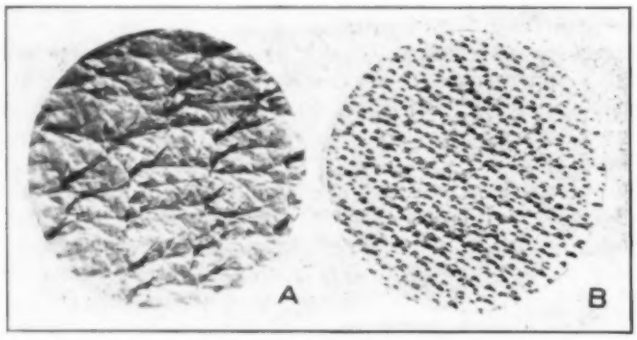
Unhairing

The next step is to free the hides from hair and epidermis and this is commonly done by putting the hides into saturated lime water containing an excess of lime and some sodium sulphide. Since these liquors are used over and over again after restrengthening, they generally contain decomposition products of the protein constituents of the hide, such as polypeptides, salts of aminoacids, amines, and ammonia, and all of these seem to play a part in this process, which is known as "liming."

After the hides have been in the liquor for several days, the malpighian layer of the epidermis is destroyed and the corneous layer and the hair may simply be

*Chief Chemist, A. F. Gallun & Sons Co., Milwaukee, Wis.

rubbed off, and this is done on a suitable machine. Sometimes arsenic sulphide is used instead of sodium sulphide to "sharpen" the limes, and similar use has also been made of lye and of ammonia. In earlier times lime was used alone, but the action of pure lime liquors is extremely slow and satisfactory results were obtained only with old liquors that had become heavily charged with decomposition products of the hides and probably also with bacteria. Another method, once widely used, was to put the hides into a warm chamber



GRAIN SURFACES OF GOAT SKIN (*A*) AND CALF SKIN (*B*) (× 8)

where the epidermis was destroyed by putrefaction. Where the cost of labor has been large compared to the value of the hair, some tanners have employed strong solutions of sodium sulphide alone to destroy the hair, the hides being practically free from hair and epidermis when hauled from the vats. An unhairing action can also be produced by dilute solutions of ammonia and by pancreatic enzymes. All of the processes mentioned leave something to be desired and the whole subject of unhairing is in need of a much more thorough investigation than has yet been made.

Deliming

Two more general processes complete the preparation of the hides for tanning: the removal of lime or other alkalis from the hides and a curious process known as "bating." The bulk of the lime is removed simply by washing, and the remainder, which has either carbonated or is combined chemically with the hide protein, is removed by treatment with dilute acids or is sometimes allowed to remain in the hides until removed by the acids present in the tanning liquors.

Bating or Puering

Bating, or puering, originally consisted in putting the hides into vats containing a warm infusion of the dung of birds or dogs and leaving them there until the "plumping" action of the lime liquors had been counteracted and the hides had become soft and raggy. Just how the early tanners hit upon this process is a matter for speculation, but the fact remains that the method appeared to be necessary to get certain desirable results in the leather. Investigations, notably that of J. T. Wood of Nottingham, seemed to indicate that pancreatin is the active constituent of the dung, and now mixtures of pancreatic enzymes and ammonium chloride largely replace the obnoxious dungs. But the question as to why we bate at all is still a moot one. Many tanners, especially those making heavy leathers, do not bate; others claim that good leather cannot be made without bating. If the object of bating were simply to counteract the alkaline swelling of the hides coming from the limes, this could easily be accomplished by reducing the hides to a nearly neutral condition, and some tanners claim that this does produce the desirable effects of bating. Recently, however, evidence has been brought forth to show that, in bating, the elastin fibers of the papillary layer are digested by the enzymes present.

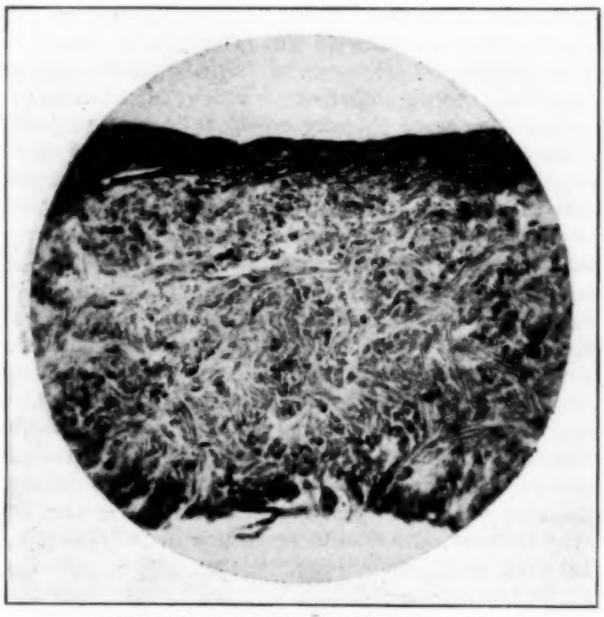
The foregoing represent what are known as the "beam house" operations and their prime object is to free the hides from everything excepting the collagen fibers and hyaline layer of the true skin, which is then ready to be tanned.

Tanning

There are numerous methods of tanning, of which only the two most important will be mentioned: these are vegetable tanning and chrome tanning. While the origin of vegetable tanning is lost in antiquity, chrome tanning is a product of the last few decades and is often referred to as the one big contribution of chemistry to the leather industry. These two processes and the materials involved in them have been the subject of the great majority of investigations made in the industry, and yet it cannot be said that we have made more than a start in the direction of solving the chemistry of tanning.

Chemistry of Vegetable Tanning Process Still Obscure

Vegetable tanning, as its name implies, consists in the conversion of hide into leather by means of material procured from plant life. The barks of trees, such as the hemlock and oak, the wood of quebracho, chest-



CHROME TANNED COWHIDE (× 15)

nut, etc., and the leaves and fruits of many plants contain matter which is soluble in water and capable of tanning hides. The hides upon coming from the beamhouse are first suspended in vats containing very dilute solutions of these tanning materials, each day or two they are moved into stronger liquors, and are finally hauled out when the color of the tan liquor has completely penetrated the hides as shown by examining a cutting in the thickest part of a hide.

Simple though this process may seem, its chemistry is exceedingly complex. Many theories of the mechanism of the process have been propounded and there is still no general agreement on any theory. The process is one in which the tanner finds he dare not deviate much from his daily practice. If the liquors become too strong or too acid, there is danger of the grain surface becoming rough or wrinkled to such an extent that it cannot later be made smooth and the value of the leather is lessened considerably. If the liquors are not sufficiently acid, the tanning action is retarded and the liquors and leather become darker in color through oxidation.

Different kinds of tanning materials often produce very different kinds of leather, but it is still a matter of some doubt as to whether such differences are due to differences in the active tanning principles which they contain or to differences in the content of foreign matter, such as acids and sugars or other fermentable substances. Some evidence has been brought forth recently to show that astringent tanning materials differ from milder ones chiefly in possessing less of non-tanning matters of acid character. Many difficulties that sometimes confront the tanner in the later processes are traceable to slight changes in the condition of the tanyards.

Vegetable Tanning Problems Suited for University Research

Much of the research required on the subject of vegetable tanning is especially suited for university laboratories. Among the more important problems in this connection might be mentioned the chemistry of the tannins, the swelling of the collagen fibers by dilute acid solutions and the opposing action of the tannins, the diffusion of the constituents of a tan liquor into the substance of the hide fibers, the effect of change of acidity upon the tanning action, and the nature of the tanning action itself. It will be found convenient in university studies of these problems to use a standard hide powder which has been placed on the market by the Standard Manufacturing Co. of Ridgway, Pa., especially for use in tannin analysis. This powder is made up chiefly of purified collagen fibers containing about 12 per cent water, 0.3 per cent ash and about 0.8 per cent of fat.

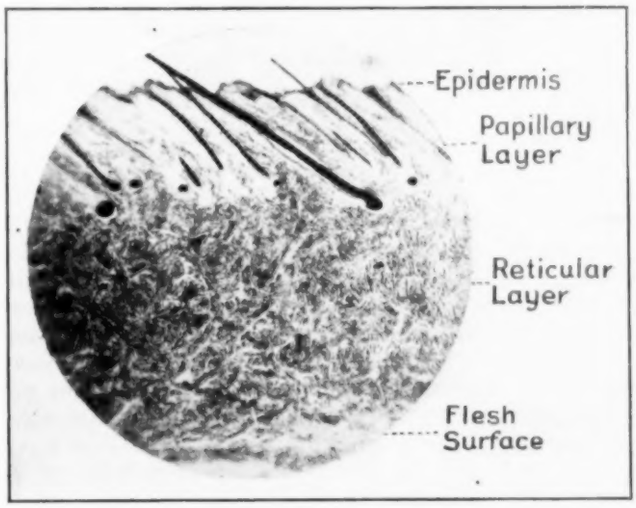
Chrome Tanning

Chrome tanning consists in treating the hides first with a solution of sulphuric acid and common salt, a process known as pickling, and then with a solution of basic chromic sulphate corresponding roughly to the formula Cr (OH) SO_4. Since chrome liquors are usually made by reducing sodium dichromate, they also contain a considerable amount of sodium sulphate. Sometimes the hides are taken from the pickle bath and put into a separate tanning bath and sometimes the chrome preparation is added directly to the pickle liquor containing the hides. After the hides have been drummed or churned in the chrome liquor for a day or more, the green color of the chrome will have penetrated them completely and they are then tested to determine whether or not the tannage is complete. This is done by keeping strips of the leather in boiling water for five minutes or longer; if they are fully tanned, the boiling water will apparently be without effect upon them, but any unchanged collagen present will be converted into glue, causing a considerable distortion of the strips. When the hides are not fully tanned at this stage, it is generally necessary to reduce the acidity by a cautious addition of alkali.

Complexity of Chrome Tanning Process

It would seem that tanning with inorganic salts and acids should be less complex than vegetable tanning, but the process is nevertheless almost bewildering in its complexity. Work now in progress at Columbia University has already shown that chrome liquors are much more complicated systems than we previously had reason to believe, although anyone who has done much experimenting with chrome tanning must have experienced the annoyance of not being able to duplicate certain results because of the variation of some unknown and therefore uncontrollable factors.

A. W. Thomas and his collaborators at Columbia have shown by hydrogen electrode measurements that the acidity of a chrome liquor changes with the time, especially just after some change has been made in the liquor, such as dilution or the addition of acids or alkalis. The acidity is markedly increased by adding neutral chlorides, such as common salt, and is decreased by neutral sulphates. They showed also that neutral salts have a similar action upon solutions of



COWHIDE FROM SOAK VATS (× 17)

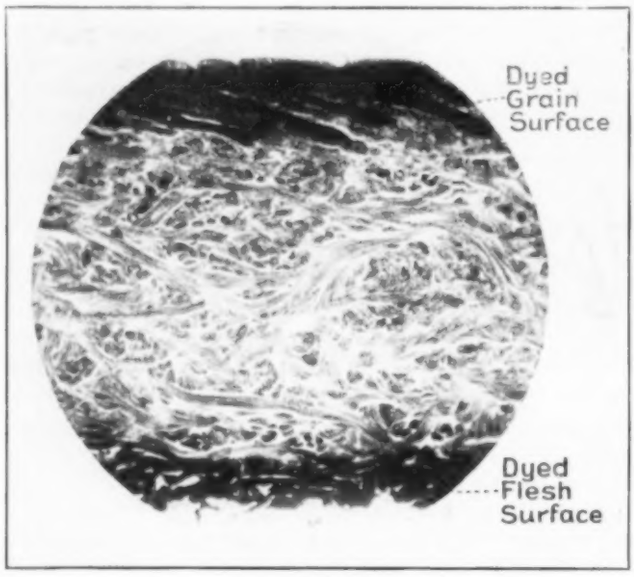
hydrochloric acid or sulphuric acid. It is quite evident, then, that before we can hope to control every factor in chrome tanning we must learn more about pure solutions of acids and salts. It is in further studies of this kind that the pure chemist can be of very great service to the industry and it is desired that he should appreciate the possibilities for applying his discoveries. An increase in the acidity of a chrome liquor retards the tanning. The addition of sodium chloride increases the acidity and, as would be expected, retards the tanning. On the other hand, the addition of sodium sulphate decreases the acidity, but it also retards the tanning. The explanation of these facts surely lies within the province of the pure chemist.

The writer has done much work on theories of tanning and believes that vegetable tanning consists of the combination of collagen and tannin, yielding collagen tannate or vegetable leather, and that similarly, in chrome tanning, we have the formation of a chromium collagenate, collagen being amphoteric. On

this basis the combining weight of collagen appears to be 750, or some multiple or submultiple of 750. This view has been contested, but its truth or fallacy should interest the pure chemist.

Fatliquoring and Stuffing

After tanning, by either the chrome or vegetable process, the hides are fatliquored or stuffed. Fatliquoring, which is applied to light leathers, consists in drumming the leather with a hot emulsion of suitable oils. If the condition of the leather is right and the



VEGETABLE TANNED CALFSKIN (× 40)

proper quantities of materials have been used, the leather will remove practically all of the oil and leave nearly pure water behind. Stuffing consists in treating the hides with greases, such as a mixture of cod oil and tallow, which are often added hot to the dry leather. The object in applying oils to leather is to prevent brittleness, to increase strength, and to impart other properties desirable for certain types of leather, such as waterproofness, etc. There is much room for experiment in the making of suitable emulsions.

Dyeing

Another important process is the dyeing of leather. A pack of skins which has been kept together through every process may emerge from the color drum with some skins light in color and others dark. Any one skin will be uniform in color, but one skin may be much darker than another. The writer has found that slight differences in the amounts of acid carried by chrome-tanned skins cause them to take different amounts of dye from the same bath, but difference in acidity of different skins scarcely furnishes the full explanation.

University Chemists Should Develop Theories

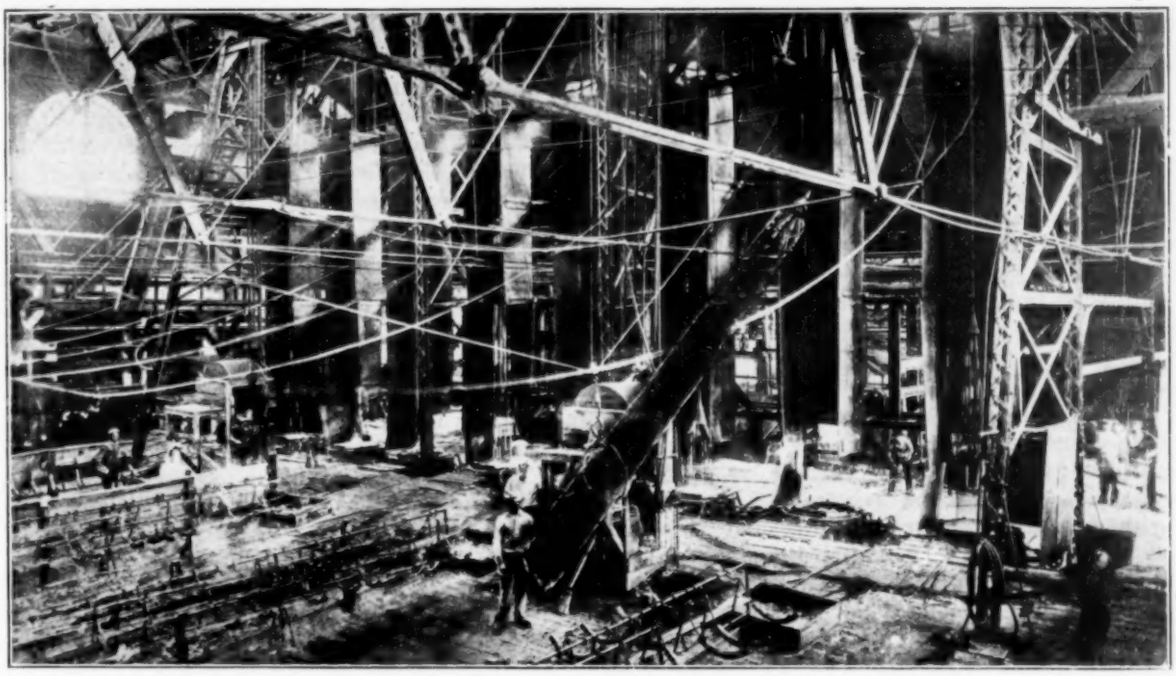
The research work which the industry needs is of two very distinct kinds, the one pertaining to the discovery of facts and of reasons for certain processes and the other the correlation of those facts and application of them to actual leather manufacture. The former requires an extraordinarily broad knowledge of general chemistry and great skill in dealing with specific problems in many different fields of chemistry. For example, in studying the mechanism of bating, the investigator should have a knowledge of both bacteriological and enzyme actions, he should be familiar with the action of electrolytes upon proteins and with the work of H. R. Procter of Leeds and others upon the swelling of proteins in certain solutions by absorption of water, and he should be skilled in preparing and staining cross-sections of the hide for microscopic examination.

At the end of his investigation he might be able to say with certainty that bating has two and only two important functions, the counteraction of the swelling caused by the limes and the removal of elastin fibers from the papillary layer. Such a statement properly substantiated would do much to elevate a now uncertain process to a scientific basis. In the study of chrome tanning the investigator must have some very refined apparatus, particularly a good hydrogen electrode, and he must have a very thorough knowledge of physical chemistry. He might be able to settle definitely the molecular mechanism of tanning and show exactly what essential rôles are played by the salts and acids present. For the purpose of solving problems of this kind the university is vastly better prepared than the tannery.

Chemists Familiar With Tannery Practice Should Apply Theories

But when it comes to correlating such facts as the university chemist might discover and applying them to actual leather manufacture, a tannery is necessary as well as a chemist thoroughly familiar with its practical workings, and this of course the university could scarcely be expected to furnish. This would of necessity be the work of the tannery chemist, and such tanneries as do not employ chemists might fail to profit by the work done at the university. For example, suppose the university chemist proved the value of bating and recommended the use of a certain type of bating liquor that was slightly alkaline. A tanner who now delimes his stock with dilute acids, but does not bate, reads of the great discovery and attempts to profit by it. He follows the instructions carefully, but the resulting leather is much inferior to what he has been making. He concludes that bating is detrimental and remains satisfied with his deliming process. He has gained nothing from the research simply because he did not have in his plant a chemist with sufficient training and knowledge of the tannery to see that good results could not be expected until the vegetable tanyard was altered to conform to the changed condition of the stock coming from the beamhouse. Before instituting the bating process, the stock arrived in the yard in a slightly acid condition. After bating, the stock was slightly alkaline. To meet this changed condition, either the tan liquors should have been more strongly acid or the stock should have been put through the usual deliming process after the bating. Thus a given discovery might be hailed as a success by certain tanners whose processes chanced to be specially suited to receive it, while other tanners would consider it a failure.

The industry needs the help of the university chemists and it also needs highly trained chemists holding positions of responsibility in its tanneries; its development will be greatest when these two groups of chemists learn to do teamwork.



MACHINE PROCESS OF MAKING WINDOW GLASS

Putting the Glass Industry on a Scientific Basis

The Role of Modern Science in the Ancient Art of Glassmaking—Developments Due to Engineering — Refractories and Raw Materials — Accomplishments of the Chemist

BY E. WARD TILLOTSON*

GLASS and glassmaking ever have had a peculiar appeal to the imagination of all peoples. Glass, possessing many of the attributes of precious jewels and in addition possessing the susceptibility of constructive formation, is particularly adapted not only for articles of use but also for pieces of art in which the form, decoration and coloring reflect the artistic sense of the glassworker. Glassmaking as an art practiced in secret for centuries has been surrounded with the glamour of mystery and the masters of the art have enjoyed the patronage of royalty and the perquisites of the nobility.

DEVELOPMENTS DUE TO ENGINEERING

During the last two centuries, however, conditions incident to the advancement of civilization have swept away many of the mysterious formulas. The establishment of the glass industry in this country marked the beginning of scientific advancement in the technology of glassmaking: the economic situation prevailing in a civilization such as ours makes impossible the maintenance of a great industry in a state of technical secrecy. It is not to be inferred that the industry is free from ignorance and prejudice or that glass manufacturers do not jealously guard certain secret processes, but it is only just to say that in no other country are glass factories more open to inspection for casual visitors and for business competitors. The glass manufacturer in general realizes that an exchange of ideas is of greater value to both parties than any doubtfully guarded secret could be to either one.

The first advances in glassmaking in the United States and the most widely known American contributions to the industry consist in the applications of mechanical appliances and the making automatic of many glassmaking processes. For example, the pressing of glass, an American invention of one hundred years ago, has passed successively through hand-fed hand-operated presses, hand-fed power-operated presses, and now certain pressed glass articles are manufactured by automatic machinery which carries out the operations of "gathering" the molten glass, pressing the article, transferring it to and conveying it through the "leer."

IMPROVEMENT IN BOTTLE MAKING

A similar development has taken place in the manufacture of bottles, bulbs for incandescent lights and other articles involving pressing or blowing or even a combination of the two operations. In the window-glass industry the process, though of more recent date, has been equally brilliant and of far-reaching importance. Machines not entirely automatic, to be sure, draw huge cylinders from a pool of molten glass, and not only is the product of a far better quality than that

*Assistant Director of the Mellon Institute of Industrial Research.

produced by the old "hand-blowing" process, but the great economic saving marks the introduction of machine-drawn window glass as a revolutionary achievement. Of the very recent developments in machine-made window glass mention should be made of a process in which "endless" flat sheets of glass are drawn and passed continuously through the leer. It is considered that this machine is an assured success. Obviously it possesses certain advantages over the cylinder machines, not only by reason of its continuous operation but also because the expensive operation of "flattening" is eliminated.

Little Progress in Plate-Glass Industry

The plate-glass industry has not experienced any spectacular developments of the nature of the inventions just mentioned; the operations as carried out at present are fundamentally the same as those of Thevart in 1688, with, of course, modern furnaces and leers and mechanical appliances for handling the glass in the several operations. This particular industry has been slow to develop in this country, but in recent years the requirements for windshields and other plate-glass fittings for automobiles have greatly stimulated the production of plate glass.

Mention should be made of "wire glass," which is manufactured by processes analagous to those employed in plate-glass manufacture. It is an American invention and represents perhaps the greatest advance in the application of plate glass for special purposes.

In the other glass industries American manufacturers have had the advantage of large resources of raw materials of a high degree of purity and of cheap clean fuel (natural gas); and while these factors have contributed to maintain the quality of American glassware on a par with that of other countries, revolutionary developments in certain lines have not been made.

FILLING END OF A LIBBEY OWENS FURNACE

Role of the Chemist and Physicist

It is, therefore, evident that American contributions to the advance of the glass industries have been largely from the engineering standpoint. It is not to be supposed, however, that the chemist and the physicist have entirely neglected these great industries. In fact, the part of these scientists has been of greater importance than is commonly supposed or acknowledged. Little has been written of the chemist's accomplishments, except, perhaps, in connection with the development of optical glass during the past few years.[1] Chemical contributions have been isolated, sporadic and, unfortunately, dimmed in the shadow of a general policy of secrecy which has resulted partly from tradition and partly from fear of legal complications. Such conditions do not make for real scientific progress in this or any other industry, but it is believed that the present is a period of transition and it is certain that great opportunities exist for the chemist and that his work in the future in conjunction with that of the physicist and engineer will transform the whole aspect of glass technology. The problems which are to be solved include the basic principles of all the operations involved and of the materials employed. The problems in connection with refractories, furnaces, fuel and raw materials are shared in common with all branches of the glass industry.

The Role of the Refractories

The pots in which glass is melted and the walls of the tank melting furnace are made from certain refractory fireclays. The curious situation is therefore presented of melting one type of silicate in a container composed of another type of silicate which is slowly but surely dissolved by the molten material. Unfortunately, none of the common metals possesses properties satisfying the requirements for these containers, and such substances as are known to be insoluble in molten glass have not yet been bonded successfully with an equally refractory and insoluble cement. The proposal has been made that the tank be constructed as a water-jacketed iron box. Walls of chilled glass would thereby be formed of the same composition as that of the glass to be melted. This would appear to be an almost ideal solution of the refractory problem, but in trial certain faults have been disclosed. Between the walls of cool and comparatively rigid glass and the channel of flowing molten "metal" there exists a zone in which the conditions are favorable for devitrification. Crystallization of some of the components of the glass occurs and these crystals are gradually carried to the working end of the tank and appear as defects in the finished product. When the chemist has succeeded in preventing devitrification in glasses of the type melted in tanks, this water-cooled tank will perhaps have a large field of usefulness.

The Pot an Important Factor

The use of green or partly burned pots and blocks is not to be considered as entirely satisfactory. Even if the pot is burned carefully in the pot arch, it is subjected to a higher temperature in the furnace. As a result, the back wall and crown are more thoroughly vitrified and subjected to considerable shrinkage, while the bottom and front walls are protected from the heat and remain more porous and do not shrink. This condition results in the introduction of large strains in

[1] For a concise review of the contributions of the chemist to the optical glass industry see A. A. Houghton, *J. Ind. Eng. Chem.*, vol. 7, p. 290 (1915). In speaking of developments in this country Mr. Houghton says: "America's contributions to the development of the glass industry, chiefly in methods of working and handling the molten glass, are epoch-making in character; along more strictly chemical lines creditable work has been done, as instanced by the Tiffany or Aurene glass, the selenium red, and others. Aside from optical glass, on which a beginning is being made, the glasses produced in this country probably are fully equal in quality and variety to those produced abroad; and in some respects America is forging ahead." For a recent report on the status of the optical glass industry, see R. J. Montgomery's "Twenty-three Types of Optical Glass," *J. Am. Ceram. Soc.*, vol. 3, pp. 404-10 (1920).

the pot walls and contributes to a lessened life by reason of breakage and for other causes.

Certainly the several operations involved in the manufacture of the pot or the block are of an equal importance with the kind of clay employed and a thorough understanding of these operations would be of inestimable value to the glass industry.

The historic glass furnace is illustrated by the open pot and covered pot furnaces in common use. These furnaces are admittedly inefficient and cannot be considered as satisfactory from any standpoint. With covered pots, especially, the heat necessary for melting the glass is generated within the furnace and must traverse the walls of the pot before it can perform its work. Even with efficient regeneration—and few of the installations can be so classified—the waste of heat is sufficient to justify the most serious consideration. Because of this the use of pots except for melting certain kinds of glass[2] may be expected to decline.

The introduction of the tank furnace has made possible the quantity production of glass which has justified and prompted the development of automatic machines. This type of furnace represents something of an advance over the pot furnace from the standpoint of heat efficiency, but still leaves much to be desired. The tank was used first for window and bottle glass, but has been adapted to melting "lime flint" or "crystal" glass, and the indications are promising that even "lead" glass may be produced in it commercially; it will undoubtedly be employed for any glass whenever the volume of production justifies.

The melting of glass by electrical energy has been the subject of much experimentation, and it is understood that elaborate trials of this principle now are being conducted. Molten glass is a fair conductor of electricity; and if the electric current can be passed through the molten glass and the heat be thereby developed within the charge, it appears that the optimum conditions of efficiency will be realized.

Raw Materials

The great developments of the glass industry during the past forty years have been associated with the supplies of natural gas. This fuel, which was ideal for the use of the glass manufacturer, is failing rapidly and even now is to be considered as a pleasant memory. The question of fuels is largely an economic one. Glass factories always have been located near the supplies of cheap fuel, but with the improvements in the manufacture of producer gas this consideration will perhaps be of less importance in the future. The necessity in melting and annealing glass of an ashless fuel and one as free as possible from sulphur and other impurities probably excludes all solid fuels except as they are gasified in the producer; and while in a measure successful, the use of fuel oil does not appear to become general by reason of its growing cost and of its lessened availability. Improvements in the design of furnaces and of regenerating systems which will admit of a more efficient application of the fuel and of a better control of combustion will be of material aid in conserving our fuel resources and in making for economy in the industry.

[2]For example, most of the colored glasses and other special glasses are used in too small a quantity to justify the use of a tank in their production. The more intensely colored glasses, in addition, are so impermeable to radiant heat that they may be melted only in pots; and pots are thought necessary for chemical reasons in the making of ruby glasses.

The American glass manufacturer is favored with large supplies of raw materials possessing a high degree of purity. The sand, lime and soda which are available are not surpassed in any country. Good as the sand is, however, it contains small amounts of extraneous minerals, containing iron, titanium and other color-producing oxides, the economic and complete removal of which would materially lessen the "color" problem in the manufacture of the finer grades of glass.

The importance of the chemical control laboratory should be pointed out in this connection. Automatic machines demand "metal" of constant viscosity, heat conductivity, "hardness"[3] and other physical properties. It is therefore important that the composition of the glass be maintained as constant as possible from day to day. When it is considered that not only does the composition of the raw materials vary in different shipments but that some of the materials—for example, the "lime" (CaO with more or less MgO)—change in composition during storage by reason of absorbing moisture or carbon dioxide, it is evident that the scientific production of even the more ordinary kinds of glass necessitates constant and adequate chemical control.

The substitution of limestone for burned lime, the addition of feldspar or other aluminiferous minerals to the batch and the use of other glassmaking materials are problems not only of economic importance but are also essential in scientifically adapting the properties of the glass to its intended use. A new source of potash would be of benefit to certain branches of the glass industry.

Problems in Special Branches of the Industry

Each branch of the glass industry has its own individual problems. In the present state of the window-glass industry, for example, there are many problems in connection with eliminating the relatively minor

TAKING OFF GLASS AT END OF LIBBEY OWENS SHEET DRAWING MACHINE

difficulties consequent on the creation of a new and great manufacturing procedure.

Similarly in the machine-production of bottles and "packers" the majority of the problems of immediate

[3]Since no glass has a definite melting point, the word "hardness" has been used to denote the temperature at which it possesses a prescribed viscosity.

importance are related to the perfecting of the several processes which are competing for supremacy. The situation is one of mobility and of rapid progress, and it appears that the man of scientific training may have an important part in the developments of the future which will determine whether each of the automatic and semi-automatic machines will have a particular use of its own or whether one of them will prove to be so superior as to be of universal application.

The plate-glass industry is waiting for fundamental developments. At present the glass is melted in open pots and from these is poured on to the casting table, on which it is rolled. A means for conveying glass melted in a tank furnace to the casting table without the introduction of bubbles or other defects would almost revolutionize the industry. The mechanical appliances for handling the huge plates of glass have been highly developed and important innovations in the annealing process have been made, but the procedure employed in grinding and polishing, in spite of recent improvements, is impressive in its awkwardness, complexity and lack of economy. A fundamental solution of this technologic problem may perhaps be the deciding factor in the future of the polished plate-glass industry.

In all these industries, as well as those represented by a smaller volume of production, there is need for a wealth of scientific data of a chemical and physicochemical nature. The chemical reactions taking place during melting require scientific investigation; the principles of annealing glass have not been wholly worked out, and the building of leers to apply these principles is necessary for scientific annealing. A better understanding of the physical properties of glass at all temperatures and of the relation of the chemical composition to the physical properties is of real importance, not only in its fabrication in automatic machines but also in the development of new glasses or of glass for specific applications.

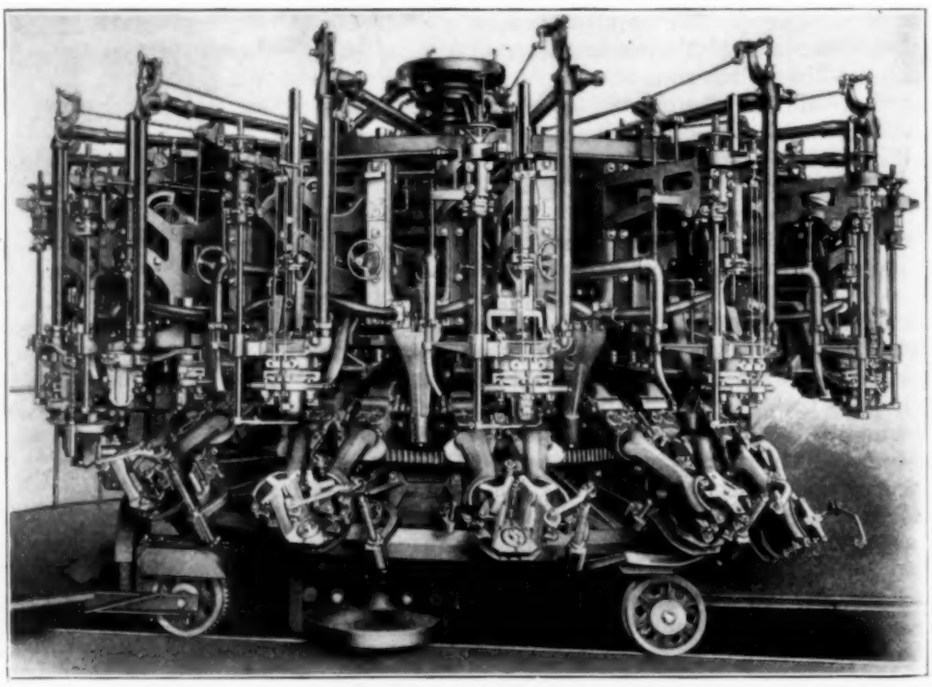
The adsorption of gases on glass surfaces and the behavior of glass to the solvent action of water and solutions is also of importance. A cheap glass of lesser solubility would find many uses and a glass of great mechanical strength would be desirable for containers which are to be used repeatedly.

To mention all the problems of the glass industry would be to discuss every detail in the manufacture and uses of glass. It should be mentioned, however, that a pink, red or ruby glass has not yet been produced in which color is constant throughout the operations and heat treatments which are involved. A highly colored red glass of permanent tint used in conjunction with the well-known blue glass, "powder blue," would form an ideal "decolorizer" and would be appreciated by the glassmaker. The use of colored glasses for signaling, for color screens in photochemical work and for goggles and spectacles to protect the eyes indicates the importance in the manufacture of these glasses of a scientific understanding of their properties, production and uses. The successful application of artificial illumination is associated closely with the glass used, and the scientific production of translucent and other glasses of the required properties offers a fruitful field of investigation for the scientist.

Accomplishments of the Chemist

Examples of what the chemist already has accomplished in the glass industries will occur to any one who is familiar with this field of manufacture. The German scientist has received his share of glory in the development of the optical glass industry, but the American inventors have been given little publicity. The American contributions of "lime flint"[1] glass, and recently of new laboratory glassware, of glass of extremely low coefficient of expansion, of glasses of peculiar properties for particular uses, and, during the war, the rapid establishment of a whole optical glass industry, under the direct supervision of scientists from the Geophysical Laboratory and the U. S. Bureau of Standards, are noteworthy accomplishments and are indicative of greater achievements when the glass industry has been put on a scientific basis.

The responsibility for fulfillment of this condition rests equally upon the scientist and upon the industrialist. It is fair to conclude that the glass manufacturer is not yet convinced that the scientist has an understanding of his problems or the ability to solve them equal with that of his practical glassmaker. It is probably true that the chemist often has failed to



OWEN 15-ARM AUTOMATIC MACHINES
This machine is capable of producing 350 gross of pint bottles per 24 hours, equivalent to the work of fifty hand operators.

[1] Invented in 1865 by William Leighton, Sr., of Wheeling, W. Va. Leighton used sodium bicarbonate in place of soda ash, which at that time contained quantities of impurities.

SOME NOTABLE DEVELOPMENTS IN THE GLASS INDUSTRY

Innovation	Date	By Whom Introduced	Place	Comments
First glass factory in America	1608	.....	Jamestown, Va.	For the manufacture of beads and bottles.
Pressed glass	1827	A carpenter, name unknown	Sandwich, Mass.	The Boston & Sandwich Glass Co., Deming Jarves, mgr.
First plate-glass factory in America	1857	.....	Williamsburg, N. Y.	Failed by reason of competition from France and Belgium.
Lime-flint glass	1864	William Leighton, Sr.	Wheeling, W. Va.	This invention nearly extinguished the old flint industry.
First regenerative pot furnace	1865	James B. Lyon	Pittsburgh, Pa.	Built at the O'Hara Glass Works,for use with producer gas
First continuous tank in America	1879	Poughkeepsie Glass Works	Poughkeepsie, N. Y.	For the manufacture of bottles.
First use of natural gas in melting glass	1882	Bradford Window Glass Co.	Bradford, Pa.	In 1884, gas was used for melting flint glass in the Riverside Glass Works, Wellsburg, W. Va.
Prepressed blank	1882	Philip Arbogast	Pittsburgh, Pa.	An important step in the development of the automatic bottle machines.
Continuous leer for window glass	1882	Cleon Tondeur	Dunhamville, N. Y.	Fox & Sons Window Glass Co. (the "rod" leer).
Continuous tank for window glass	1884	United Glass Works	Streator, Ill.	.....
Wire glass	1892	Frank Schuman	Tacony, Pa.	.....
Favrille glass	1892	The Tiffany Furnaces	Corona, L. I.	.....
Selenium ruby glass	1894	Nicholas Kopp	Pittsburgh, Pa.	.....
Flint glass melted in tank	1898	Charles H. Runyon	Rochester, Pa.	Keystone Glass Co.
Continuous leer for plate glass	1898	Marsh Plate Glass Works	Walton, Pa.	.....
Fire polishing cut glass blanks	1899	Michael J. Owens	Toledo, Ohio	.....
Automatic bottle machine	1899	Michael J. Owens	Toledo, Ohio	.....
Machine drawn window glass	1900	John J. Lubbers	Pittsburgh, Pa.	The American Window Glass Machine
Machine drawn sheet glass	1903	Irving W. Colburn	Franklin, Pa.	The Libbey Owens Sheet Glass Machine.
Flowing device	1903	Homer Brooke	Jersey City, N. J.	Used in connection with automatic machines.
Continuous leer for flint glass	1908	Maryland Glass Corporation	Baltimore, Md.	The intermittent pan leer had been in use for fifty years.
Low expansion glasses	1915	E. C. Sullivan & W. C. Taylor	Corning, N. Y.	Pyrex glass.
Hartford-Fairmont feeder	1915	Karl E. Peiler	Fairmont, W. Va.	For use with automatic machines.
Automatic tube machine	1916	Edward Danner	Toledo, Ohio	.....
Automatic bulb machine	1917	August Kadow	Toledo, Ohio	The Westlake machine producing bulbs for incandescent lights.

produce results in the glass factory; it is also probably true that the glass manufacturer has not understood what he might expect of the chemist and has not had a sufficient comprehension of science to utilize the services of the chemist to the best advantage. It is evident, therefore, that a fundamental consideration in putting this industry on a scientific basis is a more adequate training of chemists and chemical engineers in glass technology. The number of our universities which offer courses in the chemistry of glass is distressingly small and there remains to be established in any school an adequate course in glass technology in which the knowledge of the practical glassmaker is correlated with the known principles of chemistry and physics. The opportunities offered in this field and the knowledge that men of scientific training will be required in the glass industries constitute the primary arguments for the establishment of such courses of training, and the assurance of co-operation on the part of the industrialist will be of material aid and is indeed necessary in the consummation of this desirable purpose.

Such a course in glass technology should not only develop men for research and control work but should also offer to the practical man an opportunity to gain such a knowledge of scientific principles as will be of benefit to him in working in sympathetic accord with the scientific men in his factory. A mutual understanding on the part of men associated together is an essential of success.

In this principle is undoubtedly to be found the reason for instances of failure of the chemist in the glass industries. The chemist has not been trained to understand the point of view of the men making glass and the practical man has not understood the point of view of the chemist. In many industries in which the professionally trained man forms an essential part it has been found advantageous to give him in the factory an additional special training in the particular business of that factory. The recognition by the glass manufacturer of the fundamentals of this situation will quickly react to his advantage. The work of the chemist, particularly if he is engaged in research, lies within a field which properly comes under the direct jurisdiction of the chief executive of the organization. It is notable that in those concerns which have made the best use of the chemist he has come into a position of high executive responsibility. One instance, of many, may be cited in which the chief of the chemical laboratories is one of the five principal officers who report directly to the president of the company. This method of organization does not presuppose that the president is a man of scientific training, but it does assume that he has a sympathetic understanding of the relation of his business to the scientific principles involved.

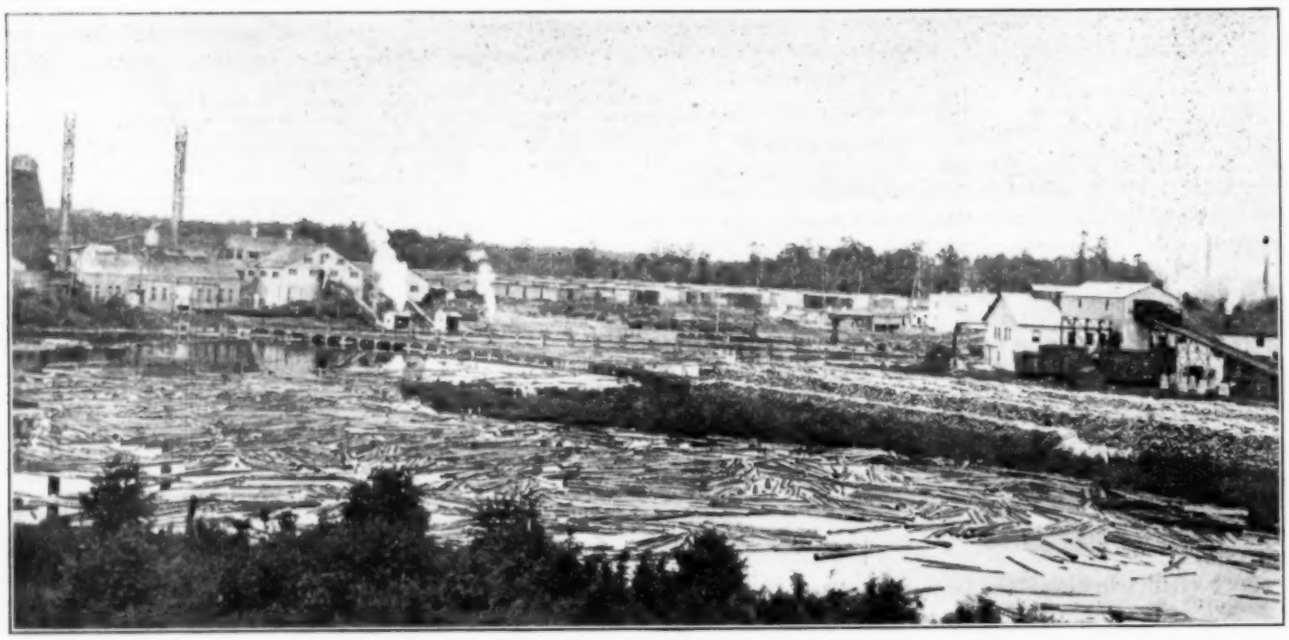
It is not to be expected that even a large number of chemists working independently and in isolation in the laboratories of a large number of glass factories will, in the highest sense, put the glass industry on a scientific basis. Science supposes organization and experience has demonstrated that united efforts are more productive than equally intense but dispersed expenditure of energy. The success which has accompanied the research laboratories established by associations of manufacturers in a united purpose for the common good may well be considered by the several glass industries. The establishment in England of the Glass Research Association under the auspices of the Department of Scientific and Industrial Research is to be taken as indicating the beginning of concerted effort to apply scientific principles to the manufacture of glass, an attitude of co-operation which is commended to the attention of the glass industries in this country. Other industries have learned that properly conducted scientific laboratories yield substantial returns.

The glass manufacturer may again read the words of an old-time but progressive glassmaker. "In an age of progress, whoever clings to the methods of the past will soon be neglected and forgotten."

Safety Glass Factory at Mount Vernon, N. Y.

The Triplex Safety Corporation of New York is operating a factory at Mount Vernon, N. Y., for the manufacture of its products. In this plant ordinary window glass is carefully graded as to size and thickness and thoroughly cleaned and dried. Two plates are then put together with sheets of celluloid between and cemented with a cement having the same optical properties as the glass.

Glass treated in this manner can be shattered by hard blows, but will not splinter. A sample made up of three such thicknesses of glass was not penetrated by a bullet discharged from a 0.45 caliber automatic.



Recent Developments in the Hardwood Distillation Industry and Suggestions for the Future

Work on the Increase and Variation of Yields of the Pyroligneous Products: Acetate of Lime, Methanol and Charcoal—Cord Sticks Cut Into 5-In. Blocks—Control of Retorting Temperatures—Central Research Organization

By L. F. HAWLEY*

IN A brief article[1] published in 1913 the writer called attention to many technical operations in the process of wood distillation in which efficiency studies would be of great value. Since that time there has been considerable progress both in research work and in the commercial application of the fundamental facts discovered.

Work on the variation in yields of products from different species of wood has continued,[2] and new plants have been built in sections of the country where the industry had not previously existed. More attention is also being paid to the use of mill wastes such as slabwood by distillation plants near which such wastes are available.

On the effect of moisture content of the wood on the yields obtained during distillation some experimental figures have been published by Palmer and Cloukey.[3] So far as we know these results have not been applied to any great extent in practice, but another development in connection with the moisture content of wood has been made by commercial plants. Formerly the drying of distillation wood was entirely by natural methods consisting of one year to eighteen months air drying. At two large plants artificial drying of the wood in three days has taken the place of this long period of air drying with resulting reduction in cost of piling wood in the yard and in interest charges on wood in storage.

Cord Sticks Cut Into 5-In. Blocks

Artificial drying has also led to another change in methods, on account of the fact that rapid drying is better obtained with small blocks of wood than with the ordinary 4-ft. stick. For the drying process, therefore, the wood has been cut into blocks about 5 in. long, and from this point onward the wood does not need to be handled, but is carried through the process entirely on the cars in which it is distilled. Although there is some extra cost in preparing these blocks and a small proportion of the wood is lost in the form of sawdust, these are more than counteracted by the lower cost of handling and the other economies mentioned above.

Control of Retorting Temperatures

A few years ago R. C. Palmer, then connected with the Forest Products Laboratory, called attention to the possibility of influencing the yields of valuable products by more careful control of the temperature of distillation. It had previously been known that by a very slow distillation the yields of a cord of wood could be increased, but Palmer showed a method by which the

Editor's Note.—In endeavoring to eliminate the use of the terms wood alcohol and methyl alcohol, the Committee on Occupational Diseases of the American Chemical Society has suggested that these be replaced by methanol or methyl hydroxide. Since methanol has been adopted by some of the leading producers, it will be used in these pages in place of wood or methyl alcohol.

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[1] *J. Ind. Eng. Chem.*, vol. 5 (1913).

[2] U. S. Dept. of Agr. Bull. 508.

[3] *J. Ind. Eng. Chem.*, vol. 10, p. 262 (1918).

yields could be increased without increasing the total length of time required for distilling a charge of wood. This was accomplished by very rapid heating at the beginning of the run with constant watching of the temperature and distillate so that the heat might be cut down just in time to prevent the distillation from "running away." This method of temperature control has been commonly adopted by the larger wood distillation plants and has been of great benefit to the industry.

Products From Wood Tar

There has recently been some development[4] in the preparation of marketable products from hardwood tar, but only a few plants are now making a complete utilization of this product by the preparation from it of marketable products. The developments along this line have been so favorable, however, that it is very likely that the utilization of hardwood tar will increase rapidly in the near future. The usual method of recovery of acetic acid and light oils from tar by distilling with steam in the wooden tar still has been studied[5] with the result that the most efficient conditions for the operation have been determined.

The products carried off in the non-condensable gas are still being lost at the same rate that they were several years ago. A few crude attempts have been made to recover a part of these products, but the subject has not been properly studied and the installations have not been very efficient or profitable.

The Acetate, Methanol and Charcoal Trio

It is seen that the hardwood distillation industry has made considerable technical progress in the last seven years, but there are still many technical details which require further study and many other points that require careful attention if the industry is to continue its present importance. The hardwood distillation industry is peculiar in that it produces three marketable products which have been of about equal importance to the industry. At one time acetate of lime may seem to be the most valuable and important product, and then methanol takes first place. The third product, charcoal, varies somewhat in demand, but in any case it makes a good third in the line. Persons frequently ask what is the cost of production of methanol or of acetate of lime, without thinking that it is an impossibility to figure the cost of production of one of these products in a practical commercial way without including the other products. It would be unreasonable to charge the entire cost of production to either product alone, and at the same time it is difficult to apportion the proper costs of the three materials. If for any reason there is a drop in the price of one of the three products and if this drop in price brings the total cost of production above the price of the products, it is necessary that some other of the three products increase in price sufficiently to make up the difference. This is probably the explanation of the rapid increase in price of methanol shortly after the Government restrictions were removed from this product and acetate of lime. The demand for acetate of lime had fallen off, and there were large stocks on hand. When the price of this product decreased for these reasons, the price of methanol had to advance in order to keep the value of the three products above the cost of production.

During the war there was such a demand for acetate and acetone that the hardwood distillation industry could not supply the required production, although previous to the war practically all acetic acid made for industrial purposes was obtained from wood as the original raw material. Several new processes for the manufacture of acetone and acetic acid were developed, and some of them were put into commercial operation. Two of these new processes are even now in operation, apparently in successful competition with similar products made from wood. This means that the monopoly of the hardwood distillation industry in acetone and acetic acid is broken and that its strength will now lie in its monopoly in methanol.

Up to the present time no promising method for the synthetic manufacture of methanol has been developed, but five years ago we could have said that no promising method for the synthetic manufacture of acetic acid had been developed. If the demand is great enough and if the price is high enough, there will be a great incentive for development work on a synthetic methanol or formaldehyde. If some process is developed which can compete with methanol from wood the hardwood distillation industry will be in a very precarious condition. It seems desirable, therefore, that the industry make efforts to remove this incentive by greater production and lower price for methanol and that it build itself up to the very highest efficiency in order to meet competition of this kind when it does arrive.

Central Research Organization

There are several points in which the industry can build up its general efficiency in order to meet this situation. One general method which has been used with very good results in other industries is the development

HARDWOOD DISTILLATION PLANT

of a central technical control or a central research organization. Any new method developed by one of the units of the industry should be made known to the others, and the details of costs and profits should be made available so that the other plants can determine whether the new development is desirable under their conditions of operation.

In connection with such a system a few technical men should be in the employment of the industry as a whole, in order to study these new developments and report on the results obtained. This is the simplest method of obtaining and applying new developments, but it is of course very slow in comparison with the operation of a central research organization, in which new ideas would

[4] *Trans.*, A.I.M.E., 1916, p. 1,387. Chem. & Met. Eng., vol. 20, No. 11, June 1, 1919, p. 586.
[5] *J. Ind. Eng. Chem.*, vol. 12, p. 684 (1920).

be actively sought for and investigated. In the end the more extensive research organization is really the most efficient, because it prevents the units of the organization from duplicating new work and it assures more careful and complete research work on new problems.

There is also a very good field along the line of general efficiency in the operation of the plant. Such simple things as pipe fitting, control of the temperature of the condenser water, and proper methods of firing the retorts and boilers may make a very large difference in the cost of production.

Higher Yields to Be Sought

It is also possible that the time has come when the attention of the industry should be directed toward increasing the production from a unit quantity of wood rather than increasing the capacity of a plant of unit cost. The cost of wood and the cost of labor are both very high at the present time and will probably continue much higher relatively than they have been previously. On this account any labor-saving device or any method by which more products can be obtained from a cord of wood should be very seriously considered. It is possible that a complete change in the design of the retorts and in the general method of handling the wood would give greatly increased efficiency under the new conditions of increased cost of wood and labor, although this change might have been entirely impractical under the old conditions. The practicability of preparing artifically dried blocks about 5 in. in length may encourage the introduction of an idea which has been several times suggested but never put into practice. This is the idea of a vertical continuous retort in which the temperature increases as the wood descends. Such retorts should be very economical of fuel, since the flue gases from the lower chamber of the retort could be used for heating the higher and cooler portions. As the operation would be continuous, the control of the temperature could be made very simple and each part of the retort could be kept at a nearly constant temperature.

Methods for the destructive distillation of sawdust would also be of value, though they would not be likely to have a very great influence on the industry, since the localities where large amounts of hardwood sawdust would be available are not very numerous. Unless larger sized pieces of wood, such as slabs and edgings and possibly some tops and limbs, were ground up for use in the process, it would be difficult to obtain enough small-sized material to run a commercial plant.

Control of Product Yields

Some experimental work started at the Forest Products Laboratory a few years ago and now in progress again after a few years interval has indicated the possibility of changing the yields of various products by the addition of certain chemicals to the wood previous to distillation. It has been shown[6] that the presence of a small amount of phosphoric acid prevents the formation of any tar; and it would, therefore, be possible to start the refining of the pyroligneous acid without a preliminary distillation in order to remove the tar. This would result in considerable economy of fuel.

Some recent experiments along this line have indicated that a small proportion of certain chemicals tends to increase the yield of methanol very considerably but with a small decrease in the yield of acid. At the present time, when there is a great demand for methanol and only a slight demand for acetic acid, a process of this kind might be very desirable. It is not impossible that further work along these lines might develop methods by which the relative yields of the different products would be controlled according to the markets, so that when methanol, for instance, was in great demand the yields of this product could be increased, possibly at the expense of some other product. At the present time there are no indications of a chemical or catalyzer which could be used to increase the yield of acid possibly at the expense of the methanol.

There is a great deal of work to do in research and in plant control and organization, in order to keep the wood-distillation industry generally efficient and progressive and make it able to meet the competition which has already arisen in regard to one of its products. Although this industry has made great technical advances in the last few years, it cannot rely on past records but must continue to advance at even increasing speed.

[6] *J. Ind. Eng. Chem.*, vol. 10, p. 264 (1918).

Tannins and Dyewood Extracts

H. O. Chute in a paper read at the Montreal meeting of the American Institute of Chemical Engineers on the Progress in Dendrochemistry stated that:

The discovery of the use of wood extracts for tanning and dyeing is prehistoric. Many of the most savage and primitive tribes have knowledge of their use.

In late years the United States has produced about 200,000,000 lb. tanning extract annually and has imported—mainly from South America as quebracho extract—about as much. Much bark, as hemlock and oak, is also used for the production of leather.

Someone has said that anyone who can make a pot of tea can make a wood extract. In an earlier day this was perhaps so, but modern methods have been introduced into this industry.

The most approved practice in the United States is to grind the woods or barks, etc., and extract in a diffusion battery under pressure. This necessitates the use of copper to give the strength and resistance to the acids which are present. Probably the most popular extractor or diffusion cell is about 5 ft. diameter and 12 ft. long, slightly enlarged toward the bottom so as to allow of quick discharge of the exhausted chips. The bottom is hinged and is the diameter of the cell and, on opening, the charge drops out to a conveyor which takes the chips to the boilers for fuel. These usually furnish all the steam necessary to the works. Each wood requires a different temperature and pressure and treatment to get the best extract. Some woods, such as quebracho, are best extracted by adding some SO_2 to the liquor to dissolve the more refractory tans Some extracts, like logwood, are oxidized, the oxidized logwood extract being called "hematine," and this is used for leather dyeing and where oxidation after applying cannot be used. On the other hand, the unoxidized logwood is preferred where bichromate mordants are allowable.

All the different woods and tannins differ in containing various other constituents. Some contain glucose, which, by fermenting, produces an acid liquor which is desirable at certain stages of the process and for certain leathers. Others contain much coloring matter and give colored leathers which are desirable or not according to their purpose. Those extracts which will not ferment, such as chestnut and quebracho, are used in connection with such fermentable extracts as hemlock, etc., or are used in the later stages of tanning.

The woods most commonly used in America for tannin extracts are hemlock and chestnut.

What seems to be a purely American invention is the production of a tannin from the chipped wood and a soda pulp from the extracted residue, thus utilizing both the fiber and tannin in the wood.

Putting the Paint and Varnish Industry on a Scientific Basis

During the Last Twenty-five Years Empiricism Has Been Rapidly Replaced by Scientific Control in the Paint Industry, Due Mainly to the Initiative of American Chemists — Research in Varnish Industry Has Dealt Chiefly With Raw Materials

BY MAXIMILIAN TOCH*

THE manufacture of paints is purely scientific, and although pigments have been made for many centuries no scientific control was observed until about twenty-five years ago.

The manufacture of varnish is partly empirical and partly scientific, but within the last fifteen years the manufacture of varnish has emerged from the rule-of-thumb to the semi-scientific state.

No scientific work of any consequence was done in Europe on paints and varnishes until American investigators had already established that industry on a sound basis, and as recently as 1906 it was evident that there were only four or five concerns in the United States which manufactured paints and varnishes that had chemists in their employ.

I do not include in these half a dozen concerns that employed analytical chemists to test the purity of the materials which they bought, but it was well known at that time that there were only a few of us who knew how to analyze mixed paint or had even a working knowledge of the composition of an oil so well known as linseed oil.

Prior to 1906 the most impossible and worthless mixtures paraded under the name of paint and it must be said to the credit of the State of North Dakota that Prof. Ladd was authorized to make an analysis of the various paints and pigments which were for sale, in order to protect firms from buying adulterated and useless materials in that state. There were many innocent errors made in the promulgation of the law in question, but the results worked out admirably, and today almost every paint and varnish manufacturer of the United States either employs a chemist directly or seeks scientific assistance indirectly.

SCIENTIFIC STATUS OF INDUSTRY IN 1906

There was at that time no literature on the subject, and I had been collecting the results of my own work since 1900, with a view to publishing a book which I intended to call "The Chemistry and Technology of Mixed Paint"; so when the State of North Dakota passed a law which broadly amounted to labeling all paints excepting those of certain composition, all paint manufacturers of the United States attempted to defend it; and the peculiar condition became apparent that men like A. H. Hooker, of Heath & Milligan; G. W. Thompson, of the National Lead Co.; Prof. Sabin, of Edward Smith & Co.; Dr. C. B. Dudley, of the Pennsylvania R. R., and I were the only chemists in the United States who had at that time any knowledge of the chemistry of paints. There were, perhaps, three or four more, like Parker McIlhenny, C. W. McKenna and others who did private work, but when it came to testifying on the witness stand as to an exact knowledge of the composition of paints, the value of such materials and an expert knowledge of the manufacture of the finished product, I was the only man, at that time, in the United States who qualified as a chemist and a manufacturer.

This was less than fifteen years ago, but since that time hundreds of able men have been engaged in work on this subject; and today lectures are delivered at our various institutions of learning, both here and abroad, so that what was empirical and regarded as exceedingly valuable, from the standpoint of secret process, is today common knowledge published for the information of all.

CHANGE IN ATTITUDE TOWARD CERTAIN PRODUCTS

During that famous trial, lithopone, regarded as a useless and cheap pigment, was brought to the attention of the paint industry, and its manufacture rose until today it is third in the list of white pigments, corroded lead and zinc oxide still taking the lead.

Chinawood oil, which only a very few knew how to manipulate, was given its proper place as a paint and varnish material, and today it is for certain purposes far more valuable than linseed oil.

Chemical and physical tests have been devised for the identification of pure turpentine, and that solvent was shown to be only a solvent and no better in the manufacture of paint than several of the petroleum solvents which evaporate completely.

I remember a very interesting experience I had more than twenty-five years ago on my first trip South to the turpentine stills, when I saw that it was the custom to add a barrel of kerosene or benzine to nine or ten barrels of the sap of the pine tree to "start the distillation properly," as some of these turpentine distillers put it, with the result that when I arrived back home and tested turpentine for specific gravity and polymerization by means of sulphuric acid, I came very nearly establishing wrong data because of this custom among the turpentine distillers.

It is very difficult for me to write a short history of the scientific development of the paint and varnish industry without repeating myself, because I have so often told of my experiences, both orally and in writing, but it does no harm to repeat one or two of my experiences for the benefit of those who wish to profit thereby.

RULE-OF-THUMB METHODS UNPROFITABLE

Once a well-known color manufacturer who, although a competitor, was a very warm friend confided to me that in the manufacture of chrome yellow he could never make any money; and he asked me to investigate and find out whether there were any leaks in his factory that his color-maker could not discover. I found, on going through his plant, that he had no chemist and that his color-maker was an ignorant man, practical to

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the last degree, but unscientific in every respect, and that he had a little note-book of formulas, one of which read as follows:

"To one pail of nitric acid add 50 lb. of litharge; then pour this in a barrel and fill it with water. Then take 100 lb. of bichromate of potash, and mix them, and you get pure medium chrome yellow."

On investigating further I found other formulas in which my friend used sugar of lead; that the color-maker dissolved a certain number of buckets of this material and added it to a certain number of buckets of bichromate of potash, with the result that the wash water showed a very large excess lead acetate which went into the sewer, and it was very easy to indicate where the loss took place; and after correcting these glaring errors I had the satisfaction of installing a chemist in the plant, and from that time on the color works in question became profitable.

Little Change in Varnish Technology

The manufacture of varnish was described four hundred years or more ago by an Italian named Cennini, and to this day the manipulation, the kettles and the tools used have scarcely changed, with the one possible exception that we know more concerning the raw materials which we use; we have been able to utilize products which were formerly regarded as adulterants; and every oil and resin used in the paint or varnish industry whose constants are indicators of its eventual physical characteristics we are familiar with.

The advent of chinawood oil has brought about a change, and I am unafraid to admit that, while I despised and discouraged the use of it in my own factory, I am now a firm believer in it until something better can be discovered.

Let us remember that fifteen years ago chinawood oil was condemned because its physical characteristics were compared with linseed oil, which shows us that it is a mistake to take a new material and judge it by an older one. Raw linseed oil, as everyone knows, dries with the aid of a drier, and when suitably mixed with the proper pigments forms a film which lasts anywhere from three to eight years, even under extreme exposure.

Raw chinawood oil, on the other hand, no matter what it is mixed with, dries with an opaque, brittle, crystalline film, which is neither flesh nor fowl. It polymerizes or solidifies when heated for twenty minutes to 420 deg. F. (216 deg. C.). It is difficult to manipulate and in unskilled hands it is a failure. But when 4 lb. of chinawood oil is heated with 1 lb. of rosin that has been partly or wholly converted into a resinate of lead or similar compound, the heat can be carried up to 600 deg. F. (315 deg. C.) without danger of the polymerization of the oil, and a varnish is obtained which, while fairly high in acid number, possesses more remarkable qualities than the best kauri linseed oil varnish ever made. This sounds strange, but it is true.

Of course, to those skilled in the art it is known that this resultant fusion of 5 lb. just mentioned must be diluted with equal quantities of turpentine or turpentine substitute, and the film so produced will not turn white after it has been permitted to dry thoroughly, even though the test sample is placed in water for weeks. When I made my first experiments along these lines I did not use the material as a varnish, but I used it as a paint oil. Of course, lead and zinc could not be used as bases, because chemical union would take place, and the compound, which I called a tungo resinate of lead or zinc, was formed, which was a viscous, ropy, gelatinous material, physically unfit for making paint ready for use. But, if the proper pigments were selected, such as graphite, lithopone, red oxide and blanc fixe, a paint could be made which remained in suspension for a long time.

As many know, I do not rely upon laboratory experiments for the finding of my conclusions; but in 1915 and 1916 I made several hundred gallons of various colored paints, omitting linseed oil entirely as a vehicle, and substituting for it a varnish made from rosin and chinawood oil, and these paints I applied to wooden structures on the Atlantic coast which were from 100 to 500 yd. distant from low tide and subject, therefore, to the heavy sea fogs of that locality. In comparison with these tests there were a number of smaller buildings painted with various mixtures of lead and zinc and linseed oil, and the conclusions arrived at were that the gloss and hardness of the resulting film, after three years, was as good for the rosin : chinawood oil mixture as for the linseed oil paint, with this exception—that the rosin : chinawood oil paint left a better surface for repainting.

Preservation of Engineering Materials

Much work has been done on the preservation of engineering materials by means of paint; and whereas we formerly thought that all paints protected, we now know that some pigments produce corrosion and others retard it to a remarkable extent.

Paints have many uses, both decorative and protective, which frequently give them a value that is inestimable, such as, for instance, the modern flat wall paints for the interior of buildings, which can be washed and which are far more economical than the dust-collecting wall papers and hangings formerly used.

Paints for Concrete Surfaces

It has been said that this is the concrete age, where portland cement is taking the place of flammable and other perishable building materials; and it is only within the last seventeen or eighteen years that methods have been devised for the coating of concrete for exterior and interior with paint materials, and these methods have been worked out purely on a scientific basis. Paints are usually made of a saponifiable base, and concrete is basic in its nature; therefore, the average oil paint is readily destroyed, and that accounted for the well-known dictum that concrete cannot be painted. But this has been completely overcome through scientific investigation, so that concrete structures of all kinds may be preserved against the acid fumes with which they may come in contact and the aqueous and other disintegrating influences which may tend to abrade them.

It is not my intention to indicate that all paint manufacture has been placed upon a scientific basis, but the enormous strides many have made in the last fifteen years and the many scientific investigations that have been made indicate that this industry will eventually be one in which empiricism will be entirely eliminated, and the credit for most of the investigation that has taken place must go entirely to America, for Germany, with all her much-heralded chemical knowledge, did very little if anything toward the scientific investigation or improvement in the manufacture of paint and varnish.

Alloys of the Past and Present

A Review of the Recent Developments in the Production of Pure Metals, Ferro-Alloys, Bronzes and Brasses and of the Increasing Uses for the Less Common Metals and Their Alloys—Research Suggestions for the Production of Special Alloys

BY COLIN G. FINK*

CENTURIES ago pure metals as derived from their minerals were practically unknown. There are a few noteworthy exceptions, such as the pillar of pure iron at Delhi, now over 1,600 years old. But in general the metallurgical processes of the past were so crude that it was not possible to produce, say, pure copper or pure nickel or pure zinc, nor to cast alloys of constant composition. The copper of the Greeks and of the Romans never even approached the "International Annealed Copper Standards" of today.

Within our present era—in particular within the latter part of the nineteenth century—metallurgical investigations were carried out here and abroad with a view of producing metals of "absolute" purity. It was found that the elimination of the last traces of impurities in copper brought about a very decided increase in the electrical conductivity of the metal. Traces of certain foreign metals in gold when removed resulted in a very malleable and ductile metal.

It was a natural inference that in general metals of 100 per cent purity were the most desirable. Metallurgical processes were being rapidly developed and improved upon. Electrometallurgy became of ever-increasing importance. Metals could be produced of a purity never before attainable.

However, it wasn't very long before we found that "100 per cent purity" was not always desirable. For example, in the case of silver a product was obtained by electrolytic refining methods which was extremely pure, purer than "Sterling" and exceptionally soft and malleable; but for actual service this "100 per cent pure" silver showed very poor wearing qualities and accordingly had to be "doped" with copper and other impurities to bring it back to "Sterling" grade.

Pure nickel could not be rolled into sheets and drawn into wire without excessive breakage. It was necessary to add a small percentage of manganese to render nickel workable. Iron containing small percentages of copper[1] or larger percentages of silicon or chromium corroded less than pure iron. Aluminum containing a little manganese was in general preferable to pure aluminum. Tungsten with ½ to 1 per cent thorium makes a better filament than 100 per cent pure tungsten. Specifications today not only point out the impurities the metal or alloy must *not* contain but include various foreign elements with limiting percentages that must be present in the product to be acceptable.

FERRO-ALLOYS

The advent of the electric furnace and the introduction of commercial electrolytic cells with fused salt baths, more than any other factors, brought about a sudden spurt in the development of our modern alloy and rare metal industries. The most remarkable advances have been made within the last twenty to twenty-five years. The electric furnace and electrolytic aluminum have made possible the production of ferro-alloys of a tenure and purity never before attained by the ordinary blast or hearth furnaces. It is very clearly demonstrated at the Chemical Exposition that a number of our capital industries, such as the machine industry, the electrical industry and the automobile industry, are largely if not wholly dependent upon electrolytic and electrothermic products and processes. Chief among these products are the ferro-alloys—ferromanganese with 78 to 82 per cent Mn, a valuable deoxidizing and recarburizing agent; ferrosilicon, up to 90 per cent Si, more effective than ferromanganese for eliminating gases in steel and other alloys and for the manufacture of silicon iron used in electrical apparatus; ferrovanadium with 30 to 40 per cent V, an indispensable addition to steels for the automotive industries where high tensile strength and resistance to constant vibrations are demanded; ferrochrome with 30 to 60 per cent Cr, for chrome-nickel and chrome-vanadium steels, armor plate, stainless steel, tool steels, etc. (according to C. B. Gibson, over 50 per cent of the chrome-vanadium steels are absorbed by the manufacturers of automobiles); ferrotungsten with 70 to 80 per cent W, for high-speed steels and magnet steels; ferrotitanium with 15 to 25 per cent Ti, a most valuable scavenger in the making of steel for rails and high-grade castings; ferro-uranium, for tool steels; and ferromolybdenum, one of the latest alloys to come into popularity, for crankshafts, gears, springs, etc.

ALLOYS FOR TOOLS

Rapid strides within recent years have been made in the development of alloys for tools. Modern high-speed tools, with 400 to 700 per cent efficiency as compared with the old carbon steel tools, were of inestimable value during the war when the element of time was a very important factor; and today, with labor and material prices soaring skyward, there are few that can afford to use an ordinary carbon-steel tool. The introduction of vanadium into the original tungsten steels greatly improved their quality and endurance.

Systematic investigations into the composition and nature of tool steels have lately been published by J. A. Mathews of Syracuse, K. Honda of Japan, R. C. McKenna of Pittsburgh, Dean J. O. Arnold and Fred Ibbotson of the University of Sheffield and others. A detailed discourse on tool steels by A. J. Langhammer of New York recently appeared in this journal.[2] He cites, as average composition of modern high-speed tool

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[1] L. T. and E. A. Richardson, MET. & CHEM. ENG., vol 15, p. 450, Oct. 15, 1916.

[2] CHEM. & MET. ENG., vol. 22, pp. 829, 889, 939, 969.

steel, tungsten 16 to 18 per cent, carbon 0.60 to 0.70 per cent, vanadium 0.75 to 1.05 per cent, chromium 3 to 4 per cent.

The introduction of the chrome-molybdenum-cobalt steel Stellite by Haynes, of automobile fame, has given rise to exhaustive tests, in particular in Canada and England. Arnold, in referring to this and similar steels, terms cobalt a stabilizer of molybdenum. Stellite alloys have gained a wide use as lathe tools, but many of these contain tungsten in place of molybdenum. The high-speed steel industry is still in a development stage, and as regards the proper intelligent operation of these special tool alloys comparatively few machine shops are fully conversant with the grinding, the best operating speed, the correct methods in heat treating, etc. Unfortunately there is a different heat treatment prescribed for each brand of tool steel. Aside from this it is usually difficult to get a machinist to realize that tool steels of today require different heat treatment from ordinary carbon steels.

Acid-proof Alloys

Most important among the acid-proof alloys are the ferrosilicon alloys containing from 10 to 15 per cent Si. As every visitor to the Exposition will concede, these alloys have passed beyond the experimental stage. Large vats, mixers and boilers for corrosive liquids have been installed in industrial plants all over the

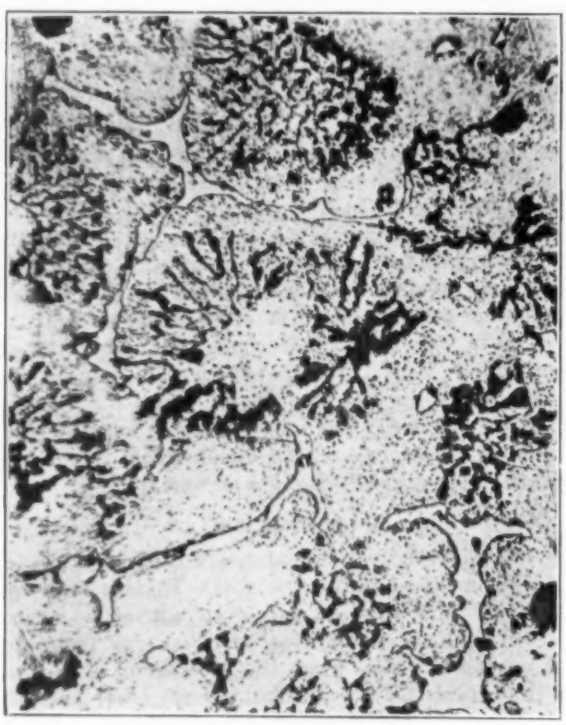


FIG. 1. ORDINARY COBALT

world. Furthermore the 13 per cent ferrosilicon alloy has been found superior to lead and to magnetite as an insoluble anode in electrolytes containing not only sulphuric acid but nitric as well. Next to ferrosilicons in industrial importance as non-corrosive alloys are the ferrochromes. They are chemical corrosion-proof but not very electrolytic corrosion-proof. Exhaustive tests have been carried out at laboratories in Niagara Falls and in New York. A. W. Clement in his patent (U. S. 1,333,706) recommends an alloy of 60 per cent chromium, 40 per cent iron for acid-resisting pipes and valves. Nickel-chrome alloys are giving very satisfactory service not only as acid-resisting material—for example, for dipping baskets in plating and pickling operations—but also as a material resisting oxidation and destruction at high temperatures. Accordingly, annealing boxes made of nickel-chrome are far outlasting the older ordinary iron boxes.

The Brasses and Bronzes

The brasses and bronzes are among the very oldest alloys in metallurgy, but it is only within the last generation that their composition and properties have been thoroughly investigated and stringent specifications drawn up for more than two dozen different grades and qualities, depending entirely upon the use to which the brass or bronze is to be put. The last two or three years have seen a complete conversion in the brass melting art from gas- or oil-fired furnaces to electric furnaces. The reduction of spelter losses is only one of the many advantages gained. A section of this year's Exposition will be devoted entirely to brass-melting electric furnaces. Types of the direct-resistance, the indirect-resistance and the arc type will be on display. Electric melting of brass costs about half that with the older combustion furnaces.

The introduction of aluminum among the cheaper metals has given rise to innumerable investigations on aluminum alloys. Many of these alloys, on account of their light weight, have been found indispensable in airplane construction. One of these airplane alloys contains 3 per cent copper and 13 per cent zinc, the remainder being aluminum. As the copper content is increased the hardness of the alloy is increased. Duralumin contains approximately 94 per cent Al, 3.7 per cent Cu, 0.6 per cent Mn, 0.25 per cent Zn, 0.43 per cent Mg, 0.6 per cent Si, 0.5 per cent Fe. It has a tensile strength of 38 kg. per sq.mm. and a Brinell hardness of 90.[2] An alloy which is an improvement on the well-known "Coney Island gold" alloy (90 to 91 Cu + 9 to 10 Al) has recently been patented by S. Shigeta (U. S. Pat. 1,319,537). It contains about 80 per cent copper, 10 per cent aluminum, 5 per cent molybdenum and 5 per cent tungsten. In color it resembles gold very closely and can be worked into thin sheets. The alloy corresponding to the formula Al_2Mg_3 (about 46 per cent Al) was carefully investigated by Waltenberg and Coblentz of the Bureau of Standards,[4] and they found that the polished surface possessed a very high reflectivity and was suitable as a mirror providing the surface can be protected from tarnish.

Bearing Alloys

According to W. K. Frank[5] a typical bronze bearing contains 9.5 per cent Pb, 10 per cent Sn, 79.7 per cent Cu and 0.8 per cent P. This bronze has a Brinell hardness of 60 and a compression of 0.25 on a 1-in. cube with a load of 100,000 lb. per sq.in. High lead alloys are plastic but wear rapidly and are difficult to produce uniformly. The best bearings have the greatest hardness compatible with the required plasticity. Of special interest are the Frary bearing alloys. One of these, for example, contains about 97 per cent lead and 3 per cent barium plus calcium. These alloys have given remarkably good service, are uniform in

[3] L. Guillet, J. Durand and J. Galibourg, *Compt. rend.* vol. 169 p. 508.

[4] Bu. Stand. Sci. paper 363, 1920.

[5] *Iron Age*, vol. 105, p. 943 (1920).

quality and readily reproduced. As compared with ordinary lead, the alloys are hard and when struck with a hammer emit a clear metallic ring. The alloys are now manufactured on large scale at Keokuk, Iowa.

Low-Temperature Coefficient Alloys

Constantan, a copper-nickel alloy with a very low-temperature coefficient, has received renewed attention within the last few years and exhaustive treatises have been published by Hunter and Bacon, F. E. Bash, D. W. Gray and others. Gray found that the addition

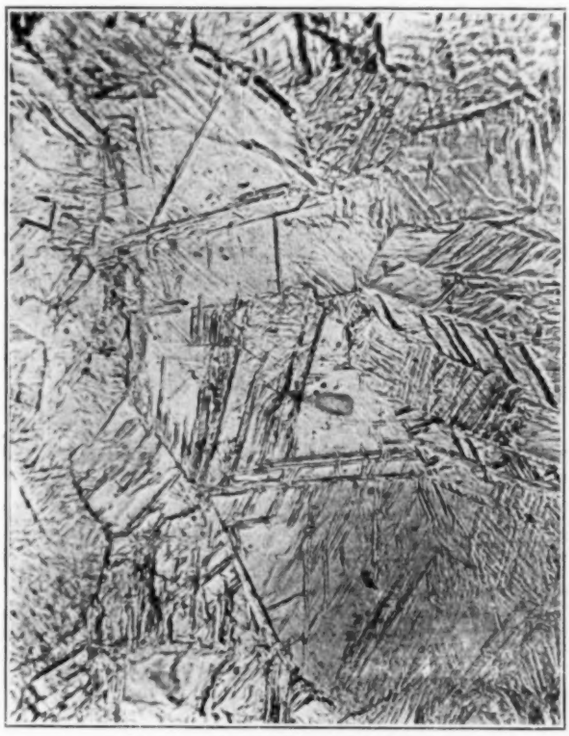


FIG. 2. CARBON-FREE COBALT

of manganese increased the specific resistance and decreased the temperature coefficient. One of his best alloys has a specific resistance of 70 microhms per c.c. and a temperature coefficient of practically zero. It is composed of approximately 55 parts of copper, 45 parts of nickel and 10 parts of manganese. For thermo-couples Bash[6] recommends the following proportions of the elements in constantan: Copper 53.18 per cent, Ni 45.71 per cent, Fe 0.26 per cent, Mn 0.61 per cent, C 0.17 per cent, Si 0.09 per cent, and S 0.02 per cent.

Increasing Uses for the Less Common Metals

Of the less common metals zirconium has been one of the most popular lately and there have been at least half a dozen laboratories, both here and abroad, investigating the properties of the metal, its alloys and other compounds. The laboratory of the Bureau of Mines at Golden has been turning out some very pure metal. At Pittsburgh zirconium steels were tried out, but details have not as yet been published.

Thallium, manufactured in limited quantities at Denver, has found application as the "getter" thallous chloride in tungsten lamps. It is one of the very few metal chlorides whose lower or "ous" state is more stable than the higher or "ic" state. A very interesting recent application of thallium is in the "Thalofide Cell," whose active principle is an oxysulphide of thallium. The cell is a new light reactive resistance of great sensitivity.[7] The electrical resistance drops 50 per cent on exposure to ¼-ft. candle. The cell is more sensitive than the selenium cell, especially on exposure to very low light intensities.

Calcium is now manufactured on a commercial basis and has found a definite and valuable application in small rectifiers and similar electrical apparatus. The Frary lead-calcium alloy has been referred to above.

The Department of Mines of Canada has carried out exhaustive researches on the alloys of cobalt. Cobalt steels have been made equal in many respects to the best tungsten steels. An interesting alloy which shows a very high degree of ductility is composed of about 20 parts of cobalt and 80 parts of nickel. Rods ½ in. in diameter can be rolled and drawn down to $\frac{3}{100}$ in. in diameter without intermediate annealing.[8]

Suggestions for Research

There are a number of metals whose alloys have been only partly investigated. Among these might be mentioned tantalum, columbium, uranium and molybdenum, all of which are obtainable in fairly large quantities and are not, strictly speaking, rare metals such as gallium and scandium.

The tantalum filament appeared on the market in 1905, but within a few years it was superseded by the more efficient tungsten filament. However, a world search for tantalum mineral deposits had been instituted by the Siemens & Halske Co. and a bountiful supply of the metal was assured. There are large deposits in Australia and the United States.

Tantalum is a metal whose properties have been carefully investigated, its manufacture at one time being carried out on a commercial basis, but today the metal is almost unknown and forgotten. Considering a few of the remarkable properties of tantalum, such as the high melting point (2,900 deg. C.) high ductility and tensile strength, insolubility in acids except hydrofluoric, the metal certainly deserves further study and research. Tantalum alloys readily with nickel, cobalt, iron and other metals.

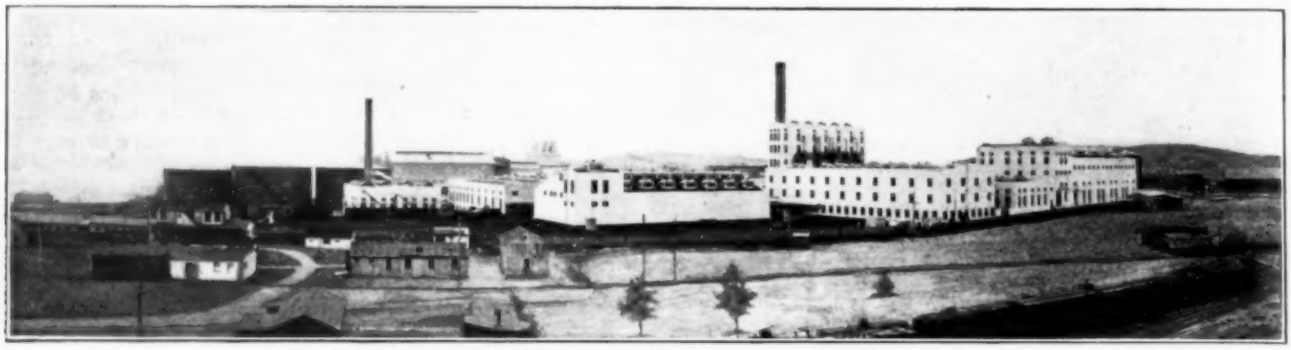
Uranium, molybdenum and zirconium have been investigated so far mainly as addition metals to steel. There is every possibility that one or all of these metals will form a valuable constituent of iron-free alloys. An alloy of molybdenum and cobalt has the same coefficient of expansion as glass, can be drawn into wire and makes a perfect seal in glass.

Another field of alloy research is the production of alloys absolutely free from carbon, sulphur and phosphorus. The author's investigations on ferronickel and on cobalt metal and its alloys have demonstrated rather strikingly that the properties of the metals and alloys undergo a decided change upon the complete elimination of the above three impurities. In the accompanying microphotographs Fig. 1 is a sample of commercial cobalt melted in the presence of carbon, and Fig. 2 is the same sample after heat treatment in hydrogen. After hydrogen treatment, cobalt, its alloys with nickel and similarly ferronickel are almost as soft as copper. The disappearance of the carbon is readily recognized in the microphotographs.

[6] Bull. Am. Inst. Min. Eng., 1918, p. 2409.

[7] Case Research Laboratory.

[8] Fink. U. S. Pat. 1,342,993, June 8, 1920.



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Science and Industrial Alcohol

Development of the Alcohol Industry Caused by Chemistry and Allied Sciences—Production Involving Raw Materials, Synthesis and Fermentation—Recovery, Involving Distillation, Rectification and Purification—Byproducts Obtained and Unsolved Problems

BY BURNELL R. TUNISON

THE industry of producing alcohol for manufacturing purposes is one of the older fields of activity with which science and particularly chemistry have been concerned. It has been considered by many that the process of alcohol production and recovery has reached a high degree of perfection. That being the case, it may be of assistance to some to note the development that has been made, the obstacles overcome and the problems which still remain unsolved.

Alcohol as such has been known and used for a great many years and even centuries prior to the study of alcohol as such and its properties. Even as early as 500 to 1000 B.C. the natives of India and China knew that by distilling certain mixtures a beverage could be obtained which exhibited marked properties as a stimulant. The Greek alchemists from the first to the fourth century A.D. learned the use of stills for simple distillation and the elements of condensation. About the twelfth or fifteenth century alcohol became recognized as a stimulant and curative agent in disease. Not until the nineteenth century, however, was the industrial use of alcohol developed. Up to that time very little progress in the art of distillation had been made, the apparatus was crude and the alcohol produced was very dilute, in addition to containing other alcohols and fermentation impurities which made it unsuitable for most industrial purposes.

The progress made in the alcohol industry may be noted from two points of view—namely: (1) The production, involving the raw materials and the fermentation or synthesis, and (2) the recovery, involving the distillation, rectification and purification.

RAW MATERIALS

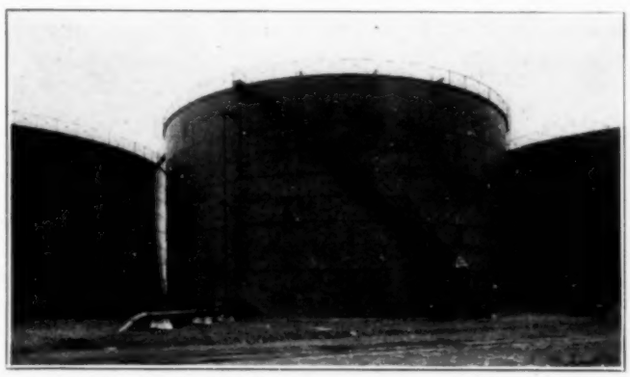
Probably the first materials used for the production of alcohol were the fruits and fruit juices which were universally used as beverages. As more was learned about the constitution of alcohol and the type of compound from which it was being made, the grains came into use. During the eighteenth century the question "What is alcohol?" led to considerable work being done to determine its actual composition and a study by the foremost scientists of the times to determine its process of formation and the nature of the compounds from which it was formed. Since the eighteenth century this constant application of scientific truths to this industry has made it safe to say that at the present day it is possible to utilize any material containing starch or sugar and many products of cellulose as a raw material for the production of alcohol. Thus the factors at the present time which determine the raw material which shall be utilized for alcohol manufacture are largely economic, the technical difficulties having been practically solved. It is true that in the use of many materials there are possibilities of much improvement in the matter of yields and efficiency of handling the process materials, and these are some of the many problems which are at present receiving the attention of experts.

At the present time the most important raw material for the production of alcohol is cane or black strap molasses. It is one of the easiest of all the raw materials to handle, requiring only dilution and acidification before fermentation. Next to molasses in importance as a raw material are the grains, corn probably being used most extensively. The choice of a raw material for alcohol production is dependent largely upon economic conditions, consequently they differ in different countries, nearly every country using a different product as a raw material. For example, Germany is noted as a country where potatoes are grown for this purpose, France uses grain and sugar beets as well as beet molasses, the United States molasses and grain chiefly. The Philippine Islands use nipa palm, China uses large quantities of rice, England is beginning to use mawra flowers, mahua and similar plants. Yucatan uses sisal waste and India uses dates and date palms.

Where we have so many possible sources of raw materials, those who are charged with the technical control of the alcohol plants of the world are very likely not to take into consideration enough of the factors or products which should be given attention. In most countries there are at least several raw materials which

should be considered. This is especially true of those plants which thrive in tropical climates. As a general rule these plants grow very rapidly and thickly over large areas and the cost is merely that of cutting and transportation to the point of utilization. For example, the nipa palm (*Nypa fruticans*) is used in the Philippines. *Commerce Reports* (July 12, 1920, page 212) states that alcohol can be made from this material for approximately 20c. per gal. There is a sufficient quantity available to produce approximately 50,000,000 gal. of alcohol per year. The present production of alcohol from this source amounts to only 2,500,000 gal. per year.

In most tropical countries the cassava and arrowroot grow very luxuriously and are excellent raw materials. They compare very favorably with potatoes as to starch content, containing approximately 25 per cent starch and



MOLASSES STORAGE—SEVEN TANKS—2,000,000 TO 3,000,000 GAL. EACH

from 4 to 6 per cent of fermentable sugars. Cassava tubers are about 8 to 10 lb. in weight. An acre of ground producing average cassava, it is stated (Press Bulletin 63, Bureau of Science, Manila, 1917), will yield approximately ten tons of tubers giving about 5,000 lb. of extractable starch, which is more than double the yield of the same area growing an average crop of potatoes.

An endless number of examples of raw materials might be given, but the above are typical. More thought should be given to the matter of raw materials for fermentation by all those engaged in the manufacture of industrial alcohol.

Two other sources of raw material for the production of industrial alcohol should be mentioned, as they will very probably be developed to some extent in this country. These are waste sulphite liquor and wood waste. The former material is available in only relatively small quantities, but in that it does contain fermentable matter and is a waste product it will probably be utilized to greater extent than at present. Wood and wood waste have been experimented with for many years, but normal conditions have not become such as to make possible the production of alcohol from this source on an extensive scale at a price which can compete with alcohol produced from the other sources.

Synthesis of Alcohol

The first chemical synthesis of alcohol is usually attributed to Berthelot. In 1854 he obtained it by absorbing olefiant gas in sulphuric acid, diluting the product and distilling it. It is also claimed that Hennell (Simmond's "Alcohol," p. 10, 1919) in 1827 succeeded in identifying ethyl sulphuric acid in a quantity of sulphuric acid into which Faraday had passed olefiant gas. Hennell in 1828 is supposed to have distilled this ethyl sulphuric acid with water and a little sulphuric acid and obtained sulphuric acid and alcohol.

Because of the relative cheapness of the raw materials for fermentation and the ease of making them very little attention has been paid to the various methods of producing alcohol synthetically. In recent years, however, where unusual conditions exist alcohol has been produced synthetically on a commercial scale. In localities where raw materials for fermentation are not abundant or where cheap power is available, such as are the conditions in Norway or Switzerland, alcohol is produced synthetically from acetylene. Calcium carbide is produced in the electric furnaces and acetylene from the carbide by the action of water. Two methods are used in the production of alcohol from acetylene:

1. Acetylene is hydrogenated by catalytic means and ethylene is produced. The ethylene is dissolved in sulphuric acid, and alcohol and sulphuric acid are formed upon saponification.

2. Acetaldehyde is produced catalytically from the acetylene. The acetaldehyde is oxidized to acetic acid or reduced to alcohol by means of catalyzers. Consul W. O. Kent of Berne, Switzerland, has described (1917 *Commerce Reports* 102, p. 426) an equipment for the production of 7,500 to 10,000 tons of alcohol per annum by the above means.

One of the newer developments for the production of industrial alcohol is its production from the waste gases from coal carbonization plants. The gases given off during the coking of coal contain appreciable quantities of ethylene. This ethylene may be separated, purified and dissolved in sulphuric acid and ethyl sulphuric acid formed. This may be readily converted by saponification to alcohol and sulphuric acid. Extensive experiments have been carried on in England with the result that it is claimed by H. F. Grady (1919 *Commerce Reports* 219, p. 1,460, also 1920, 21, p. 506), who describes the operation of a plant at the Skinningrove Iron & Steel Works, that 1.6 gal. of 95 per cent alcohol can be obtained from the gases produced by each ton of coal carbonized. The report of the British Inter-Departmental Committee on the production and utilization of "power alcohol" states that sufficient ethylene can be obtained from the gas works and coke-oven gases of Great Britain to yield annually up to 150,000,000 gal. 90 per cent alcohol. Experimental work along this line is being done in the United States and our own production may soon be supplemented in this manner.

Fermentation

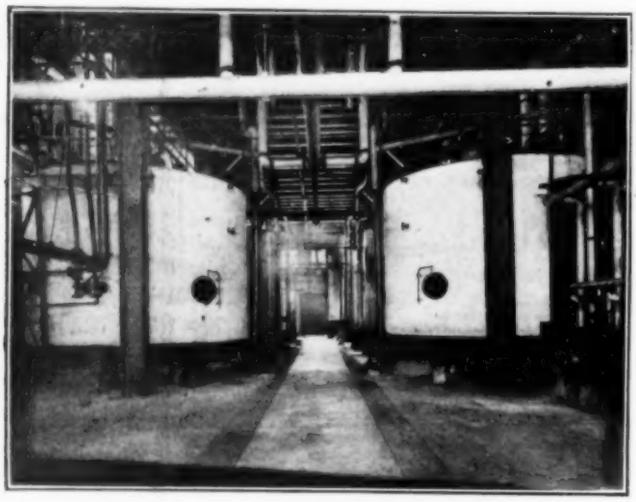
Although the production of alcohol from fruits and grains has been known since the beginning of the Christian era, it was not until the seventeenth century that any attempt was made to study the mechanism of its formation. In 1659 Willis stated that a ferment was a body in a state of decomposition, its particles being in constant motion. This motion could be imparted to other bodies capable of fermentation. In 1689 the German physician and chemist Becker thought that fermentation was a process similar to combustion because of the similarity of the waste gases evolved. He also stated that only the different varieties of sugars were capable of alcoholic fermentation.

Liebig held that sugar was mechanially decomposed as a result of molecular motion, and that the yeasts

themselves were a product of the reaction and not its cause. Another theory explaining alcohol formation was that sugar was taken in as a food by the yeast, and alcohol and carbon dioxide were given off.

Berzelius regarded fermentation as a catalytic process.

Although, little by little, knowledge was acquired concerning alcoholic fermentation, very little progress was made until the beginning of the eighteenth century. On account of the microscopic size of the yeast cells, definite knowledge concerning them was not obtained until the development of the modern microscope. Although



60,000-GAL. ALCOHOL STILLS

some of the earlier investigators had seen yeast cells, it was not until the microscope reached a high state of perfection that the fungi were carefully studied. During the early part of the eighteenth century much was learned concerning the specific properties of these microorganisms, their nourishment, growth, multiplication, etc.

In 1836 Cagniard-Latour (*Ann. Chim. Phys.*, 1838, vol. 68, p. 206) believed that from the results of his researches the yeast must be a living organism and was very probably a plant. Several other investigators about this time confirmed the conclusions that the yeasts were vegetable organisms and that they reproduced by budding or by spore formation.

Traube in 1858 explained that fermentation was due, not to the yeast cell itself, but to certain substances which were produced or secreted by these cells. However, this theory was discredited for many years.

The nineteenth century brought forth the famous controversy between Liebig and Pasteur as to the cause and mechanism of fermentation and the settlement of the question thus brought about. Liebig believed that the ferments were unstable nitrogen-containing substances, formed by the action of air upon plant juices containing sugar. These easily decomposable ferments he thought were in a constant state of degradation or decay. This decomposition imparted a corresponding chemical motion to the atoms of the sugar; and thus the sugar itself was decomposed with the production of alcohol. Pasteur eventually proved that the theory advanced by Traube was essentially correct. At the present time it is believed that the organisms capable of causing fermentation belong to one of the three groups of lower fungi—bacteria, yeasts or molds.

The bacteria attack not only carbohydrates but proteids and to some extent fats and other organic bodies. Frequently acids are produced by their action, but they are not producers of alcohol.

The yeasts which are the most important as producers of alcohol are monocellular organisms. The yeasts are the source of production of enzymes. These enzymes are the active fermenting agents. The yeasts are more or less imperfectly classified as to species, varieties and races. The various yeasts were carefully studied and classified by Pasteur, and since his time investigation has greatly extended our knowledge in this field.

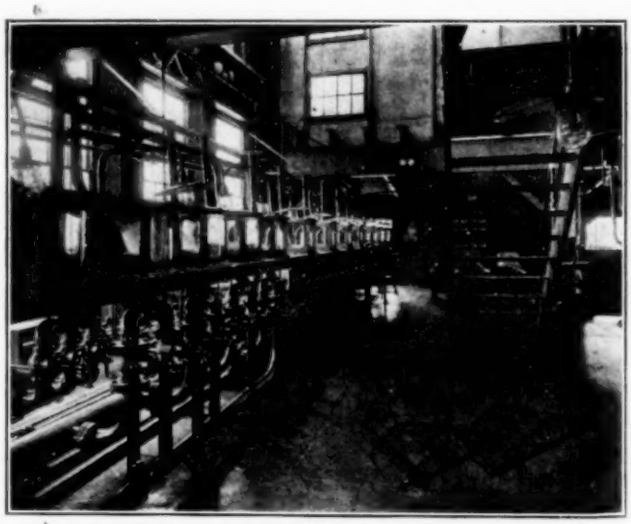
The work of Pasteur also showed that because of the fact that yeast is a plant it requires nutritive substances of organic, nitrogenous and non-nitrogenous as well as mineral form. The chief non-nitrogenous organic nutritive substance for the yeast is found in sugar. It is usual practice to add yeast foods for the proper cultivation of the yeast.

E. C. Hansen, stimulated by the work of Pasteur, investigated the life history of individual alcohol-producing yeasts and developed the method now in use in all modern plants of procuring a pure yeast by cultivation from a single cell.

E. Buchner (1896) was the first to demonstrate that an extract could be obtained, by crushing yeast cells and subjecting them to high pressure, which would ferment sugar to alcohol and carbon dioxide as a result of the monocellular enzymes which were thus liberated.

Modern Conception of Fermentation

As now understood, the enzymes are nitrogenous compounds, either albuminoids or very closely related to albuminoids in composition, which occur in vegetable and animal organisms. Their function in the life



CONTROL FLOOR OF STILL HOUSE, SHOWING ALL CONTROL VALVES AND TAIL BOXES FLOWING ALCOHOL AT RATE OF 60,000 GAL. A DAY

processes of the organism in which they exist seems to be to transform the more insoluble food materials to a soluble form in order that they may be more readily assimilated by the organism. These enzymes may be classified into groups according to a kind of action which they exert. The proteolytic enzymes which convert protein materials into simpler bodies, such as peptones and amino acids, are of secondary importance in the production of alcohol.

There are three principal types of enzymes which convert the complex carbohydrates to simple ones: 1. The diastatic enzymes which decompose starch. The resulting products are dextrine, maltodextrine and maltose. The principal enzyme of this type is diastase (amylase), which is usually obtained from malt—that is, germinated barley. Other diastatic enzymes are obtained from the molds. 2. Maltase is an enzyme which decomposes maltose into fermentable dextrose. Maltase also occurs in malt as well as in many yeasts. 3. Invertase is the enzyme which inverts cane sugar, producing a mixture of dextrose and levulose. Invertase is found in malt as well as the yeasts.

Zymase is the enzyme produced by yeast cells which directly produce alcohol from the monosaccharoses such as dextrose and levulose. Zymase, while it produces alcohol directly from dextrose and levulose, cannot produce alcohol from sucrose or the disaccharoses nor from

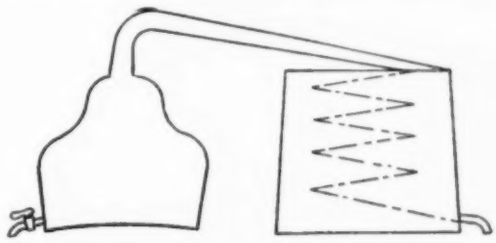
DENATURING BUILDING

starch, and the other enzymes do not produce alcohol directly, but prepare the material for the action of the zymase. Thus diastase transforms starch to maltose, maltase converts this into dextrose, invertase changes cane sugar into dextrose and levulose, which are acted upon by zymase.

There are other enzymes which are not of particular interest from the alcohol production point of view.

Theoretically when sugar is converted into alcohol we should expect to obtain only alcohol and carbon dioxide. Practically, however, the fermentation is always accomplished by the formation of byproducts which decrease the amount of alcohol recovered. Yeast is an organism which consumes sugar for its nourishment and propagation, and also converts sugar into other substances besides alcohol and carbon dioxide during its metabolic changes, thus reducing the percentage conversion. The products other than alcohol formed in the fermentation are usually glycerol, succinic acid, acetic acid, butyric acid, lactic acid, propionic acid, formic acid, higher alcohols and ketones, aldehydes, with sometimes small quantities of various esters (ethyl acetate, butyrate, caproate, etc.).

Chemistry and biology have brought the process of fermentation from the point where it "just happened" and the results were sometimes one thing and sometimes another to a point where it is possible to always obtain the products desired and to eliminate to a great extent those not wanted. However, there are still great opportunities for improvement in the yields obtained and the elimination of undesirable reactions. Progress has been made in the utilization of special ferments for the production of other alcohols and ketones and in this field of fermentation great possibilities are before us. Even in this day of much knowledge concerning fermentation we do not know exactly what the enzymes are nor just how they produce the change from starch to sugar,



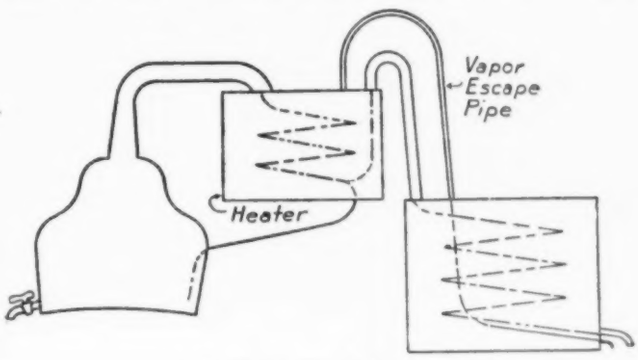
POT STILL

sugar to fermentable sugar, fermentable sugar to alcohol. We do not know just why one enzyme will produce ethyl alcohol and why another will produce butyl alcohol, glycerol or acetone. If we knew some of these things, who knows how much more we could accomplish by the process of fermentation? Wonders have been accomplished, but there still remain many fields to conquer.

A tremendous amount of work has been done and great progress has been made in working out the commercial application of the fundamentals learned concerning the process of fermentation, such as yeast growth and development of yeast, the media in which these yeasts thrive, saccharification, etc. The preparation of the raw materials has been a specialized problem and separate processes have been perfected for the handling of the different raw materials and the preliminary treatment of them which is necessary before fermentation. The process of saccharification, or the transformation of starch material into fermentable sugars, has reached a high state of perfection and all types of starchy products may be efficiently utilized.

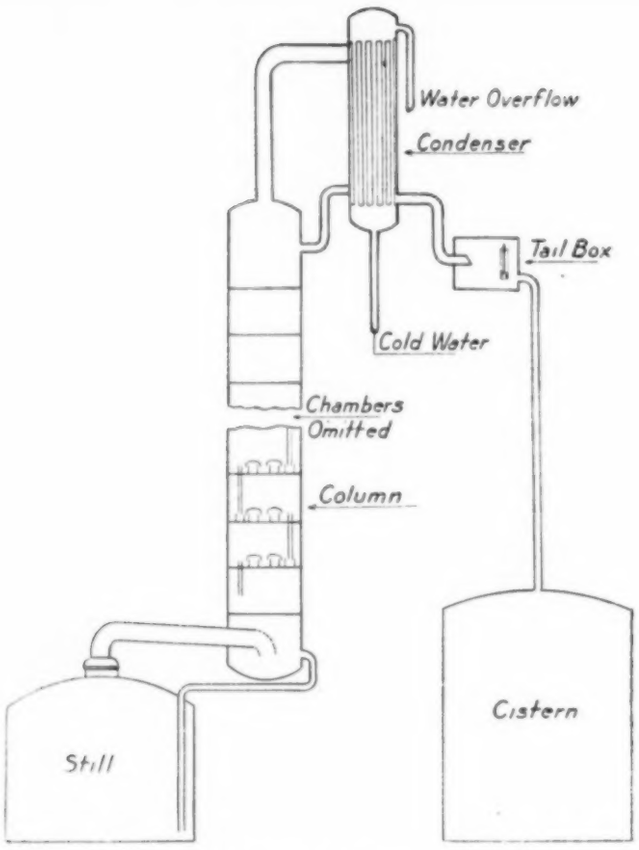
Distillation and Rectification

While the first crude stills for the production of alcohol from beverages were constructed before the beginning of the Christian era, it was not until about the

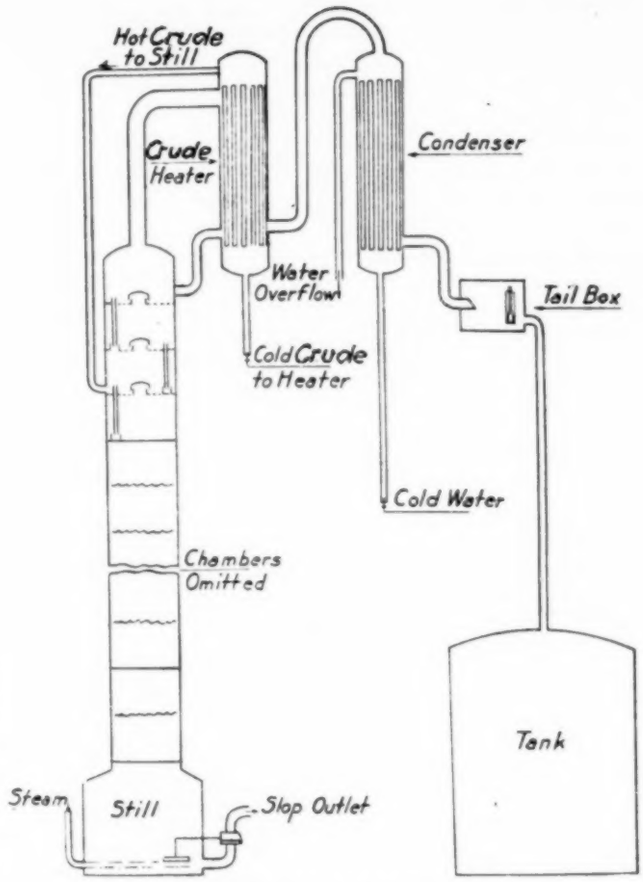


POT STILL WITH HEATER

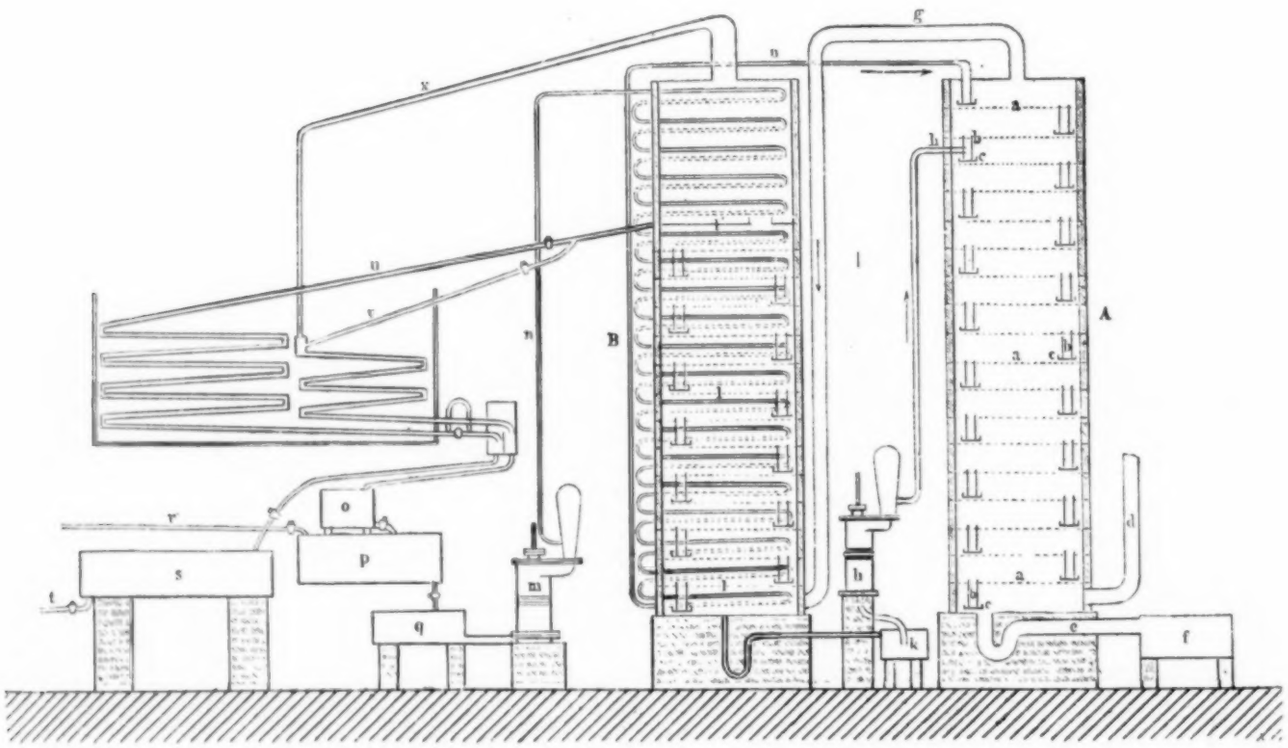
fifteenth century that any particular progress in the construction of the apparatus was made. As the fundamentals of chemistry and physics were learned they were gradually applied to the distillation of alcohol. In the eighteenth century it had been learned that by a simple distillation concentrated alcohol could not be obtained. They knew that if they were to start with a solution containing 5 per cent alcohol the vapor would



SIMPLE KETTLE AND COLUMN



SIMPLE CRUDE ALCOHOL STILL

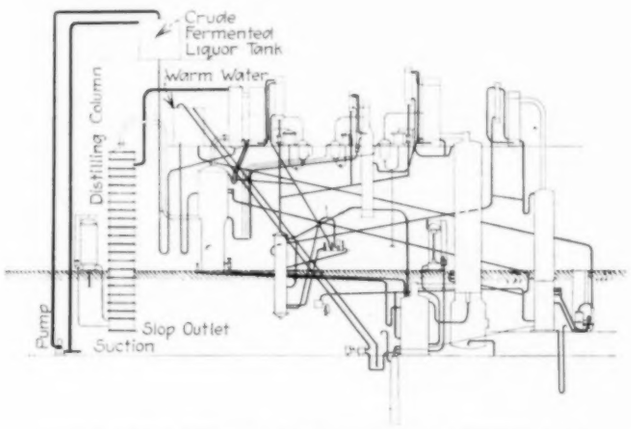


A, analyser; *B*, rectifier; *a*, perforated copper diaphragms; *w*, pump, forcing wash through zig-zag tube *u* to top of *A*; *g*, pipe leading spirit-vapour to bottom of rectifier.

DIAGRAM OF COFFEY'S PATENT STILL

contain over 40 per cent alcohol, but by condensing this and continuing the distillation, the concentration of the alcohol in the original solution having become less, the vapor from it also decreased greatly in alcoholic content. By redistilling the condensate they found that the alcohol content could be greatly increased. That is, if the condensate had an alcoholic content of 30 per cent the first vapors from such a solution would contain nearly 80 per cent alcohol.

The first distilling apparatus for the production of strong alcohol on an industrial scale was invented by



GUILLAUME SYSTEM DIRECT DISTILLATION AND RECTIFICATION

Edward Adam in 1801. This was a simple pot still which was heated over an open fire and which contained a heater. This heater condensed a part of the vapor from the still and the uncondensed portion of the vapors was made to bubble through the condensate before passing up to the condenser. The excess condensate was returned to the still. Progress was made gradually until 1832, when Coffey invented the still the principles of which are embodied in present-day apparatus. At the present time two general methods are utilized in the distillation of alcohol.

Many producers of industrial alcohol subject the fermented material to a preliminary distillation. This separates the alcoholic liquors from most of the yeast, water and other impurities of the fermentation. This alcohol still contains too high a percentage of aldehydes, water and higher boiling components (fusel oil) to be used commercially, so it then undergoes a secondary separation or rectification.

Some of the later types of apparatus combine the primary distillation and rectification into a continuous operation, the fermented crude entering at one point and the finished alcohol passing out at another.

The diagrams show the development of the apparatus for the production of alcohol, including the present complicated types.

Alcohol forms mixtures with water which distill at a constant temperature when the pressure is kept constant, without change of composition. At 760 mm. pressure the mixture of constant boiling point distills at 78.15 deg. C. and contains 4.43 per cent water (by weight) (Young, *Trans.*, Chem. Soc., 1902, vol. 81, p. 710). Since this temperature is lower than that of either pure component, it is impossible at ordinary pressure to obtain pure alcohol from a dilute aqueous solution by distillation and rectification only.

The grades produced as commercial products at present contain between 94 and 96 per cent alcohol and are usually sold as they are taken from the rectifying columns. For some particular uses, however, alcohol is often purified by passing it through a filter containing carbon black or charcoal. Sometimes it is necessary to give the alcohol a chemical purification in addition to or in place of the treatment with carbon.

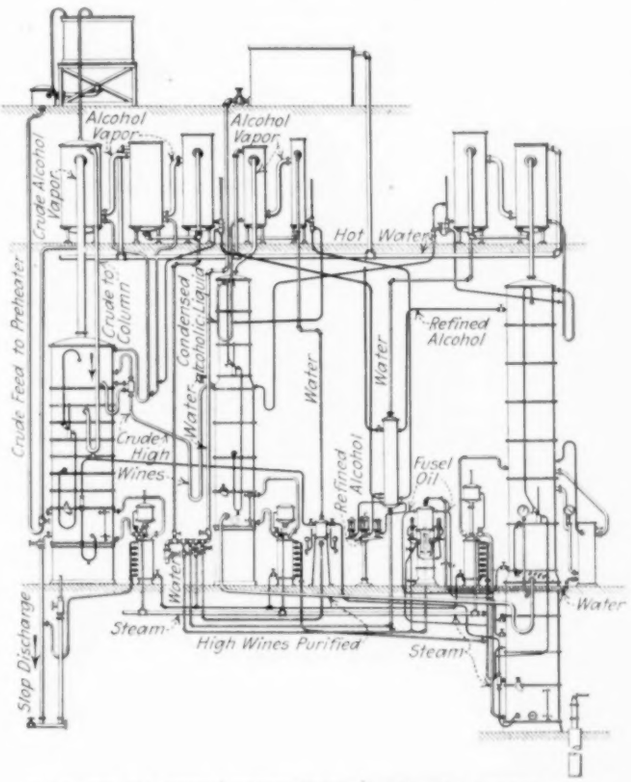
Ethyl alcohol also forms an azeotropic mixture with benzene with a boiling point of 68.25 deg. C. at normal pressure, and with water these two liquids give a ternary constant boiling mixture at a temperature of 64.85 deg. C. By a very careful study and application of the complex laws of physical chemistry concerning phase reactions, Young (*Trans.*, Chem. Soc., 1902, vol. 81, pp. 7-10) proposed a very ingenious method for dehydrating or producing absolute alcohol.

Byproducts

Scientific men have not neglected those waste materials which are incident to the production of industrial alcohol.

In alcohol fermentation carbon dioxide is formed in large quantities. Many of the modern plants have covered their fermentation tanks and are recovering this gas which finds a ready market.

Not many years ago fusel oil was considered a thing to be avoided as much as possible and that which was necessarily obtained was thrown away. Uses have been developed for this mixture of higher alcohols until today because of the demand there is considerable work being



BADGER-BARBET CONTINUOUS DISTILLATION AND RECTIFICATION SYSTEM

done toward the production of a synthetic fusel oil or the development of a ferment which will make a much greater proportion of these now very valuable products.

The fusel oil has been separated into its components by careful methods and efficient apparatus so that such products as the amyl, butyl and propyl alcohols are

obtained in a relatively pure state and are in substantial demand in the chemical and pharmaceutical industries. These alcohols as such are important solvents and are necessary raw materials for the synthesis of countless compounds.

During the primary distillation of the fermented material the crude alcohol is separated from the other components. Even today this mass of waste or "slop" in some localities is discarded. In others, however, the yeast cells are separated from the mass and are utilized in the production of plastics used in the manufacture of buttons, combs, brushes, phonograph records, etc. The slop is evaporated and the organic matter burned in some plants and the potash content recovered in the ash as a material suitable for use in fertilizer manufacture. In other cases after evaporation the organic matter is charred and the potash materials are removed by washing with dilute acid. The result is a very efficient decolorizing carbon and the removed potash salts may be purified as desired.

During the ordinary fermentation process an appreciable amount of glycerine is produced. This may be recovered.

Accomplishments and Problems

Chemistry has made the production of large quantities of practically pure alcohol an industrial reality. The application of chemistry and allied sciences to other industries has developed uses for industrial alcohol until at the present time the consumption of this necessity in the United States alone amounts to approximately 100,000,000 proof gallons per annum. Because of these sciences we have learned the composition of alcohol and its application in the production and synthesis of countless essential commodities. Chemistry has taught us the raw materials which could be used and the possible amount of alcohol which could be obtained. Biology has taken the process of fermentation and has learned its secrets and has developed fungi, determined conditions and applied these to particular raw materials so that at the present time results are obtained which were thought impossible relatively a few years ago. Engineering has rendered great assistance in the working out of the mechanical apparatus for the preparation and handling of the materials to be fermented. Chemistry has developed processes for the synthetic production of alcohol so that it may be obtained in a number of ways only a few of which at present are commercially applicable because of the relatively cheap sources of fermentable materials. The waste products in the manufacture of alcohol have been taken and made available and necessary for the production of essential commodities as previously indicated.

Chemistry, physics and physical chemistry with the assistance of engineering have improved the process of recovery and purification so that now it is possible to obtain at pleasure any grade of alcohol from 5 or 10 per cent alcoholic content, which was the best obtainable until the above sciences were applied, to absolute alcohol of the highest purity.

Of the possibilities for future development much could be said if time and space were available. There are undoubtedly a great number of raw materials available in quantity for the production of the various alcohols which have never been utilized nor their possibilities carefully studied. As economic conditions change and as the supply of petroleum products, particularly motor fuels, diminishes the demand for alcohol will greatly increase and the available raw materials will be utilized to a far greater extent than at present.

The process of alcoholic fermentation has been developed to a high state of perfection. There are desirable results, however, which have not been obtained. In the production of ethyl alcohol, as has been indicated, the formation of other products than ethyl alcohol takes place. It would be desirable to control the fermentation a little more completely in order that only ethyl alcohol would be produced, and then if desired the other products of the usual alcoholic fermentation, such as the higher alcohols, could be produced separately.

Then there is the problem of the utilization of cellulose materials. These materials have been utilized to some extent, but it is usually necessary to prepare them for fermentation by digestion with acids under pressure.

May we not look forward to the day when a ferment will be found and developed which will make possible the direct fermentation of cellulose to alcohol on a commercial scale? That will eliminate the present necessity of hydrolyzing this material by means of acids, heat and pressure. Being thus able to produce alcohol from any material containing sugar, starch or cellulose, our alcohol may be obtained at a very low figure and our chemical industries will be assured of rapid growth and development.

There are many latent possibilities in the utilization of the slop. By proper fermentation it may be possible to obtain paying quantities of the higher organic acids. These compounds have been produced to a limited extent, but there is no general commercial utilization of these materials. This phase of the industry well warrants the time and consideration of our fermentologists.

The distillation and rectification of alcohol have been perfected until no great development is expected. The fundamental laws involved have been discovered, studied and apparatus worked out which correctly applies them. Probably the greatest development in the future will be in the matter of control. It should be possible to maintain the complicated apparatus for the distillation and rectification of alcohol under the conditions for which they were designed more continuously than is now the case.

From the alcohol made available and the byproducts of its manufacture it has been possible to place before the markets of the world a list of commodities which have done much to raise the standards of living of all countries. The application of the sciences to the alcohol and allied industries in our country has assisted in the growth of a large chemical industry in addition to making possible the manufacture of many of the primary necessities of our people. Let us hope that our chemical and allied industries may continue to expand by the application of correct scientific knowledge in order that our independence may become a greater reality.

New York City.

Fuel for Motor Transport

The Fuel Research Board of Great Britain has just issued an interim memorandum entitled "Fuel for Motor Transport." In reference to alcohol it states the production of considerable quantities of power alcohol from vegetable materials grown in the United Kingdom is not economically possible owing to insufficient acreage, high cost of production and raw materials being important foodstuffs.

The Future of the Animal Products Industry

Future Research in This Industry Will Be Centered Primarily in the Byproducts, From Which Are Manufactured: Leather; Fertilizers; Oils and Fats; Lard, Oleo Stock and Margarine; Soap; Glue and Gelatine; Organotherapeutic Products and Enzymes

By WILLIAM D. RICHARDSON

THE old era of the animal products industry passed away without notice and the new era began without ceremony. That era witnessed the passing of the small abattoir with its wasteful and insanitary methods and the establishment of the packinghouse on a scale adequate to handle the great livestock output of the Mississippi Valley and to vend the multifarious products and byproducts of the industry in the markets of the world. The efficiency, sanitation and commercial economy of the large establishments became proverbial. Mechanical refrigeration was generally substituted for natural. The refrigerator car came into common use and mechanical methods were highly developed and gradually extended into all departments. During this period the aim was to utilize in some way all parts of the animal body, not necessarily in the best way—the byproduct industry developed too fast for that—but at any rate in a manner which would yield profitable products.

This point marks off one period of development—everything but the bleat, squeal and moo (as the common saying is) were utilized somehow, some way, but not necessarily for the highest use or in the most economical way. The new period imposes this task on the chemist—to put all products and byproducts to the highest possible use. Nothing less is demanded and will be enforced by present economic exigencies.

The chemical laboratories under the old order were organizations with mixed functions, partly analytical, partly research and partly operative, and one chemist might be called upon to perform all sorts of work, from sampling fertilizer or tallow to operating a part of the plant. For many years routine analytical work predominated—in fact, still does predominate—and it has only been in recent years that definitely and separately organized research laboratories have been thought of.

The Meat Business

To the casual observer it might seem that, considered individually, carcasses of animals are handled and meats consumed by the human race today in very much the same manner as they were by neolithic man. The principal difference exhibited today is in the direction of an ever-increasing number of byproducts; then (one is reminded of the story of the apple and its core) there were no byproducts. Speaking seriously, man today eats meat when he is hungry for it and when he can get it, the best cuts taking first place, as has always been the case. Meat being a natural and desirable food, it is not likely that customs will change.

There are, however, three directions of work for the chemical investigator in connection with the general meat food industry: First, the more complete utilization of the edible portions of the animal body; second, the prevention of waste or, rather, the more complete utilization of waste parts and trimmings in the retail market and in the home; third, more complete investigation of the dietetics of meats. So far as the further utilization of the animal carcass is concerned, it may be said that in some respects the dietitian is in advance of the public taste and in other respects public practice has gone ahead of the work of the dietitian. However, both scientific and practical dietetics, and the public taste are coming closer and closer together on the subject of greater conservation of animal food products and apparently the progress is as rapid as can reasonably be expected.

The wastes and trimmings of the retailer, particularly the fats, are generally fairly well utilized, although improvements, particularly in preventing spoilage, are desirable. Wastes in the home continue and much food of value is regularly thrown out to be utilized at best in rendering works and at worst as filling material. The cure for waste of food materials in the home lies in general public education on these matters, enforced by the economic pressure of food scarcity and high prices.

In spite of the great advance made in the chemistry of foods and dietetics in recent years, our ignorance is still profound and this field will tax the efforts of our investigators to the utmost for many years to come. The chemistry of proteins and fats, their assimilation and metabolism, are realms whose borders only have been explored. Of the composition and functions of the vitamines we are still in almost complete ignorance nor, although it would be rash to predict, does it seem likely that definite information will be forthcoming in the immediate future.

The Preservation of Meat Food Products

Of the four general methods for the preservation of foods, low temperatures, sterilization, salting processes and desiccation, all but the last are in general and extensive use in the meat-packing industry. Cold storage divides itself into two procedures: The preservation of foods above the freezing point, and their preservation in the solid frozen condition. The main principles of handling for both these methods have been carefully worked out, but there are still a number of details which will bear further investigation. The circulation of purified air in cold storage chambers, the complete regulation of humidity therein, the prevention of desiccation of frozen products and further knowledge of the chemical changes which occur in foods stored above the freezing point are among the problems requiring further attention. It is now well established that meat food products can be held in the solid frozen condition without essential deterioration for practically unlimited periods of time. When the product is not in solid frozen condition, however, certain very slow changes ensue.

Preservation by means of heat sterilization may be

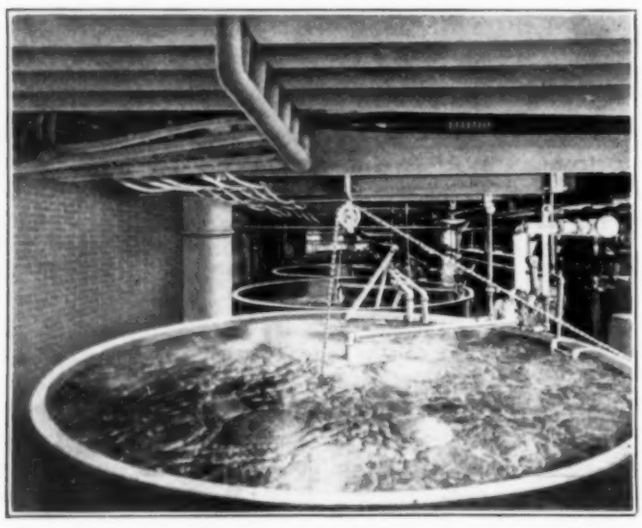
said to have reached its full development some years ago and no essential changes have been introduced recently. To be sure, the machinery and the details of handling have undergone continuous evolution. The lining of tinned cans has received much attention and a greater variety of products is placed on the market each succeeding year, but the principle developed by Francois Appert in 1804 is still applied.

The great need in salting and curing processes is for more speed in the operations. Some advances have been made in the case of salted tinned meats, but for the standard kinds of cured pork hams, beef hams and bacon the old slow methods prevail limited by the speed of osmosis. While it is eminently desirable to hasten these processes, this must be done at no sacrifice of flavor or texture. In principle, the processes of today are what they have always been and improvements relate chiefly to quantity handling of product, sterilization methods to prevent spoilage and a general extension of cleanliness and sanitary methods.

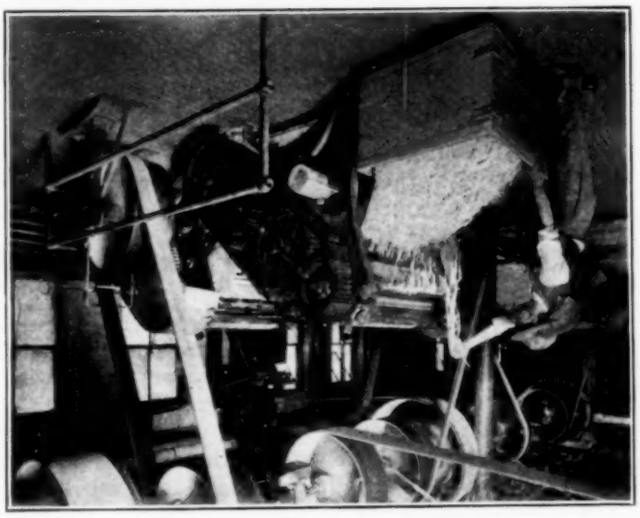
Desiccation, one of the oldest methods of food preservation, is applied only to a limited extent in the meat packing industry. There is little or no public demand for dried meat products, public taste in nearly every instance preferring fresh or undried, juicy, succulent products. Before desiccation can be largely used for the preservation of meat products there must be a change in the public preference. At present drying is definitely applied only to the types of sausage of the "summer" variety, to "dried" beef, and incidentally to hams and bacon in connection with smoking. There are a number of patents in existence for drying processes, but when a manufacturing development depends on the public taste there is no certainty when or how the development will take place. There ought to be a large market for desiccated meats, but at present this market does not exist.

Chemistry of the Animal Body

Our slowly developing knowledge of the substances and the transformations concerned in living phenomena is dependent on the general development of organic chemistry for its extension. It is dependent now upon biological tests, feeding experiments and bacteriological tests *in vitro* for information of the mere existence of many substances whose chemical nature and composition cannot even be foreshadowed at present. The immensity of this field may be emphasized by the statement that no single organ, no individual tissue, no fluid of the animal body has been investigated with any degree of completeness of results. Blood and milk have perhaps received more attention than any others, but nevertheless our information is far from complete in these cases. A more complete knowledge of the chemical nature and constitution of the substances making up the different tissues and fluids of the animal body cannot fail to make its impress on the future development of the byproducts of the animal industry. Since the bearing of this new and increased information of the general chemistry of the animal tissues cannot be determined in advance, a technologic discussion of the results at this time would be hypothetical and futile.



STEAM COIL LINED KETTLE FOR BOILING SOAP. CAPACITY 10 TO 12 CARLOADS OF FINISHED PRODUCT



MILLING TOILET SOAP

Organotherapeutic Products and the Enzymes

What is true with respect to our general knowledge of the chemical substances composing the tissues and fluids of the body applies with special emphasis to the active principles of the secretions of the ductless glands and some other organs. The hopes for organotherapy have risen and fallen during recent years with the discovery of a new physiological action, the isolation and identification of an active principle and, on the other hand, the failure to discover, or the failure of extracts to produce, uniform results in all cases. Nevertheless, there should be no discouragement as to the future usefulness of these preparations or the importance of this branch of industry.

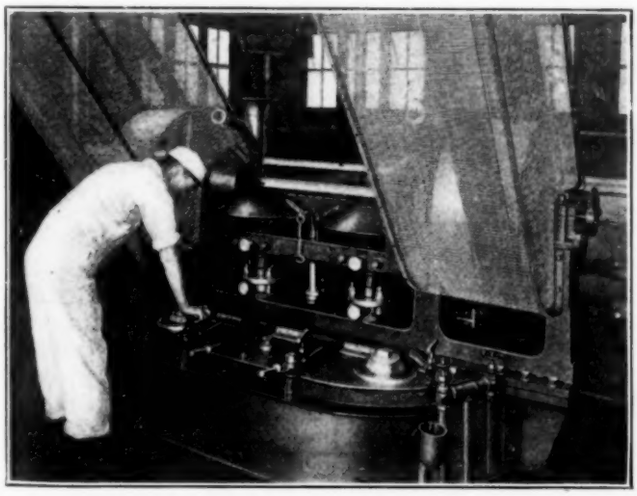
Passing over the great need for further knowledge of the physiological action of the active principles and extracts, one of the primary manufacturing needs is methods of standardization. Standardized products are the primary requisites. Products of good keeping qualities are also required, since standardization would be well nigh useless if the product did not maintain its original standard for a considerable period of time. Perfect standardization can be attained only with the separation and identification of the active substances. The only active principle certainly identified up to the present is that of the suprarenal gland, generally known as adrenaline, dioxy-phenyl-oxyethyl-methylamine. The problem of the precise nature of the active principle of the thyroid remains unsolved. Much work has been done on the pituitary body. Ovarian and testicular extracts

are at present somewhat out of favor with the medical profession and much physiological work remains to be done with them and the extract of the corpora lutea. The same remarks apply to the parathyroid, the thymus and the pineal gland. The nature of the digestive ferments, ptyalin, pepsin, the enzymes of the duodenum and of the pancreas remain to us as very incompletely solved chemical problems. The chemical nature of the hormones, gastrin and secretin is still unknown. In all directions a vast field lies open for the chemical investigator of these and other active principles of glands, organs and fluids. While the manufacture of organo products can never be a large part of the meat products industry, from the standpoints of chemistry, medicine and humanity this branch is of the utmost importance. A great future lies before it.

Tanning and Leather

While the entire industry of animal products has suffered because it was an old industry filled with ancient customs and prejudices, leather manufacture has been stigmatized by tradition perhaps more than any other branch of it. Ancient industries which were among the arts practiced by primitive man can be put upon a modern and scientific basis only by herculean effort. New industries start from a scientific mark without the handicaps of age, tradition and rules of thumb.

Scientific progress in the art of vegetable tanning has been lamentably slow, in mineral tanning much



OLEOMARGARINE CHURNING ROOM

more rapid. The extreme slowness of the one may be accounted for by the adherence to old formulas and methods and because the tanners have not made sufficient effort to gather around them scientists of intelligence and imagination to apply their knowledge to the old processes. Modern tanning practice is still full of salting, plumping liquors, bates, drenches, puers, pickles and tanning liquors of unknown or partly known composition and mode of action.

Fortunately—and this also is a bar to progress—in the hands of experienced masters of the art, leather of the highest quality is regularly turned out by the old methods. The things most needed in the industry may be stated briefly as increased speed and certainty of quality in the product. The speed of tanning is limited chiefly by the slowness of diffusion, but quality of product is limited by the uncertain composition of preparatory fluids and tan liquors, both of which are subject to control. At every step problems present themselves. The salting of skins and hides, including the time factor, the chemical and physical changes which occur during soaking, the changes taking place during the liming of hides, methods of deliming and the chemical and physical nature of vegetable tannage, all require much further study.

The development and use of synthetic tannins is a great problem in itself which will occupy the time of many research chemists. All along the line the substitution of definite chemicals or mixtures of chemicals and definite bacterial cultures for uncertain mixed cultures will gradually take place. It should be said that much has already been accomplished in this direction, but much more remains for future accomplishment. There are perhaps more possibilities for improvement by the chemist in the tanning industry than in any other branch of the animal byproduct industry.

Fertilizers

Of the fundamentals of inorganic plant nutrition we know little more than Liebig taught us. Of the specific functions of the mineral substances found in the ash of plants we know next to nothing. The fertilizer business today consists in supplying phosphates, potash salts and nitrogen compounds in suitable chemical and physical condition for application to the soil, and the farmer himself generally supplies humus in the form of barnyard manure and lime as carbonate of lime or gypsum if these are required.

The association of the animal products industry with the fertilizer trade began with the supplying of blood, tankage and bone to the latter, at first in the undried condition, later dried and ground. Gradually blood and tankage were absorbed more and more in animal foods, bones were taken over by the glue and gelatine manufacturer, so that at the present time the supply of these raw materials is steadily lessening to the vanishing point, and in the near future, if the chemist continues to keep the industry in the line of progress, none will be available for the fertilizer trade.

The fertilizer material of the immediate future will consist of phosphates from phosphate rock and basic slag, potash salts from the Stassfurt and Alsatian deposits and various salines, nitrogen compounds from natural and artificial nitrates, and ammonia compounds from the coking industry and from cyanamide. The entire fertilizer business is tending more and more toward concentrated product and herein lies the fertilizer chemist's greatest opportunities in the immediate future, since the idea of concentration carries with it the production of synthetic products and highly concentrated salts.

Concentrated phosphates are still made chiefly by the old superphosphate process depending on the separation and concentration of phosphoric acid from calcium phosphate and the acidulation of rock with the acid thus produced. Considerable work has been done on the reduction of phosphates in the electric furnace with the subsequent oxidation of phosphorus to phosphoric anhydride. Various difficulties have been encountered in the development of this process which the chemist of the future will have to overcome. At present by far the greatest bulk of phosphate entering the fertilizer trade is still in the form of ordinary acid phosphate containing approximately 16 per cent available P_2O_5.

Although the war forced the United States to take the first steps in the manufacture of ammonia from the

nitrogen of the air by the direct process as well as the indirect, this manufacture is not yet established. Ammonium salts still have their source in the coke industry and nitrates in the salt mixtures of Chile. The price of fertilizer nitrogen is higher at present than it has ever been and there appears to be a considerable shortage of nitrogenous materials. Nevertheless, there is still a question about the commercial practicability and success of some of the fixation processes unless practiced on a very large scale with cheap power. Considerable experimental work has been accomplished in connection with fixation by means of nitrides, but the development of these processes also lies in the future. Cyanamide, however, is firmly established in the fertilizer industry, as are also ammonium salts derived therefrom.

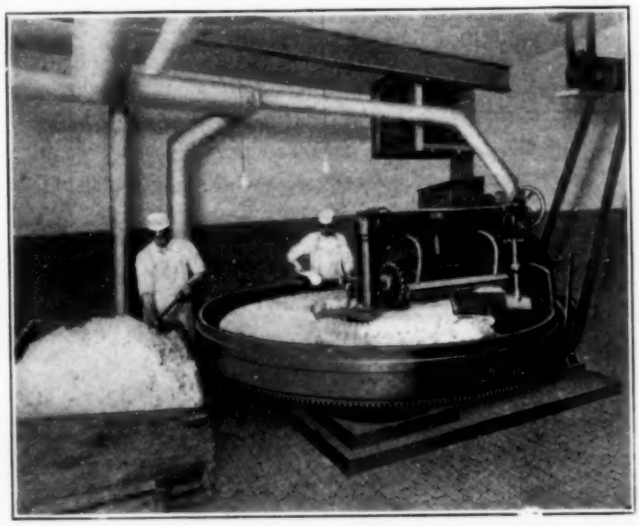
The American potash industry starting up at various points chiefly in the Western United States and working on different sources of raw materials suffered a setback when the armistice was signed, but later, when potash imports did not reach the expected tonnage, took a new lease of life. Some of the plants, particularly those manufacturing from the Nebraska lakes, have been in the main successful throughout. Others, such as those working on the mother liquor from salt crystallization at Great Salt Lake and Saldura, Utah, achieved partial success. The kelp potash plants were successful during the war and the Searles Lake industry, having encountered many difficulties, according to reports can now turn out potash salts containing less than 0.5 per cent borax. There is a grave question about the success of any of these enterprises in competition with foreign potash salts when these are received at our ports in the quantities demanded by our industries, but it is hoped that since the industry has been established here it will continue.

There is one thought which should be taken to heart by American chemists generally in connection with this situation and that is whether any other great country of the world would fail to utilize to the best advantage as a source of potash and organic chemicals the great kelp beds of the Pacific Coast. The Department of Agriculture has given encouragement to the development of the kelp potash industry and still maintains the experimental plant at Summerland, Cal. That the industry will be well established some day seems certain, but it is unfortunate that it went out of existence, practically speaking, with the signing of the armistice.

Oils and Fats

Twenty years ago the oil and fat chemist labored under the impression that his knowledge of oils and fats was in the main sufficiently complete and satisfactory. Today he realizes that he is only beginning to obtain information of these most important substances —important alike to manufacture and technology, dietetics and physiology. After Chevreul showed that animal and vegetable fats could be hydrolyzed into glycerol and fatty acids, the principal effort of chemists and technologists, resting on this information, was to utilize these two products in the best way for the manufacture of soap, candles and refined glycerine. In dietetics fats were considered as so much fuel, in physiology as substances which were stored up in the body to be consumed as fuel in time of need. The great functional importance of fats physiologically has come to be appreciated only within the past few years.

The proximate composition of the fatty acid complex of several of the fats has been worked out, but even this work is very far from complete. When the composition of any of the well-known fats themselves in terms of their glycerides is considered we realize at once our almost total ignorance. We do not know the composition completely even of the fatty acids of the common fats, and we have only the slightest information in regard to their mixed glycerides, and most of this is hypothetical. The isomers of oleic, linolic, linolenic and clupanodonic acids, the chemical changes taking place in rancidity and other little understood oxidation processes, and in the drying of oils, all require much more work for their elucidation. The mechanism and reactions of digestion and assimilation of fats and of their synthesis in the body remain unsolved. Of the real basis of the shortening power of fats and oils our knowledge is negligible. Opinions vary as widely as the results of tests thus far conducted and theory on the subject is chaotic. On the technological side there is still a waste of fats and loss of quality at various points which can and will be overcome. Rendering and extrac-



OLEOMARGARINE ROTARY WORKERS FOR WORKING IN THE SALT AND SQUEEZING OUT THE EXCESS MOISTURE

tion processes are both susceptible of improvement. Refining processes also are incompletely developed and considerable betterments may be looked for in the future.

Since color, bad flavor and high free acid are generally associated with one another, improvements which improve one generally improve the others. Prompt handling, low temperatures and the avoidance of the use of strong chemicals, so far as this is possible, should be the rules in the handling of fats. It is becoming more apparent that excessively high temperatures which have been used in refining processes may not be desirable from several standpoints. We may hope to see in the not far distant future a better correlation of our knowledge of fat constitution and physiological function with production and refining processes.

Lard, Oleo Stock and Margarine

The chemical and mechanical features of lard manufacture have been very well worked out and do not require the immediate attention of the chemical technologist as much as other departments of the fat and oil industry. On the other hand, while the rendering of

oleo fats is handled in a satisfactory manner, the methods in vogue for seeding and pressing the stock are primitive. Mechanical seeding apparatus has been introduced at a few points and attempts have been made to improve and simplify the presses. It is likely that within a few years mechanical seeders will be universally used and that a suitable press will be developed capable of displacing the present clumsy and laborious pressing methods. Like all the old processes, however, those at present used for the manufacture of oleo oil and stearine produce excellent products, and this fact is as usual a bar to progress.

Legislation, tradition, custom and the public taste have all been factors in retarding the development of the oleomargarine industry. Legislation has always favored the butter industry and favors it at the present time. Following tradition and custom, oleomargarine manufacture adopted many of the methods used for handling butter, whereas it is altogether likely that simpler manufacturing processes could be devised which would make a perfectly satisfactory product. On account of adverse legislation which permits butter to be colored and denies or penalizes the privilege in the case of margarine, manufacturers are inclined to sacrifice flavor to color and unfortunately public taste commends this policy. Legislation should not be partisan in this respect. If color is used in the one case it should be used in the other or the privilege of coloring should be denied both industries.

In recent years there has been a great increase in the variety of oils used in margarines. Formerly oleo oil, cottonseed oil and neutral lard were the three chiefly used. At the present time the list has been extended to include coconut oil, peanut oil, soya bean oil, hydrogenized product and others. Many so-called nut butters composed largely or exclusively of coconut oil have been placed on the market, and while these have not proved the equal of standard oleomargarines in point of flavor, keeping quality or melting point range, they have met with much public favor.

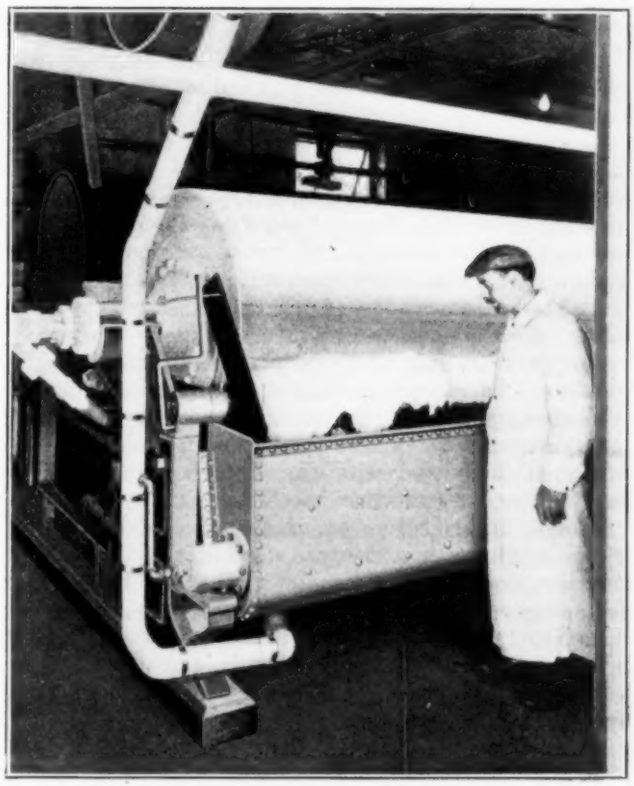
The oleomargarine industry is steadily increasing, although the consumption in the United States is still behind that of most European countries. Indeed, our consumption of butter and butter substitutes taken together is below that of many foreign countries. The future development of the oleomargarine business will probably lie in the direction of an increasing list of raw materials, improved emulsification, and simplification of the mechanical processes used, with a general tendency away from the methods used in the manufacture of butter, thus allowing the industry better opportunity to work out methods specifically adapted to its own needs.

Hydrogenation

While hydrogenation, or the conversion of unsaturated into saturated fats by addition of hydrogen, has been well accomplished, the reverse process, dehydrogenation, remains unmastered, nor is there available at present any chemical information capable of foretelling how or when this development may be achieved. Hydrogenation has been brought to a meritorious first development, and the industry, satisfied for the present, does not appear to be undergoing any marked technological developments. Aside from more active and cheaper catalysts, which are always in demand, some of the desiderata are methods for purifying low-grade oils so as to fit them for hydrogenation and render them incapable of killing the catalyzer before the reaction is completed, a method for the manufacture of cheap, pure hydrogen other than the electrolytic way, and methods for purifying hydrogen as produced by the steam-iron process. However, for one so recently developed the industry is in a very healthy, thriving condition.

Soap

The soap industry also has come into the modern era following a long train of ancient methods and customs. On the manufacturing side two broad improvements are needed: first, greater speed in the saponification and boiling processes, and secondly, quick mechanical methods of molding the liquid product into bars. Even though the first reform may be long delayed on account of the necessity for separating glycerine lyes, there can be no valid excuse for greater delay in instituting the second procedure. The tedious processes of framing,



CONGEALING REFINED LARD ON REVOLVING TANDEM ROLLERS

chilling, slabbing, cutting and pressing ought all to be condensed into one continuous operation. This is the next important practical step in the industry.

This is not the place to dwell on ethical reforms in industry, but it would seem from every standpoint that the soap industry would do well to rid itself of the gross adulterations practiced therein and return to the manufacture of purer soaps. All fillers and adulterants added to soaps, without exception, lessen the detergent power, having none in themselves or much less than the soap to which they are added. Sodium resinate and sodium silicate may be excused on the grounds of easier solubility when used in small proportion. They can hardly be excused when used in extreme quantities. Other fillers, such as mineral fillers, petroleum oils and the recently advocated clay, can scarcely be justified on any grounds except that one manufacturer begins it and the others follow suit to meet competition. There is no substitute

which is the equivalent of pure soap in detergent value. The manufacture of soap based on detergent value has not been undertaken. Some attention has been given to solubility (particularly in the case of textile soaps) and also to lathering qualities in the case of ordinary toilet and laundry soaps, but for the most part soap manufactures and soap products rest upon an empirical foundation or worse. Special forms of soap to catch the public eye and preference have been introduced without number and unwarranted claims are frequently made for them in extravagantly worded advertisements so that on the whole the public is uninformed or misinformed as to what constitutes good soap and buys largely on the basis of whim and prejudice—not a good foundation for the marketing of any standard commodity. Usually and perhaps always it is the advertising or the premium rather than the quality and the price which sells the soap. The public needs reforming as much as or more than the manufacturer.

Glue and Gelatine

On both the chemical and physical sides collagen and gelatine offer an unlimited field for the investigator in pure science. The problems connected with these substances are innumerable. Their chemical composition so far as it has been unraveled differs as greatly as their physical properties from the other animal and vegetable proteins and even from elastin. A more complete understanding of these substances must await the time when our chemical knowledge of the entire protein group is more fully developed.

The industry has developed empirically and the rules of thumb have been handed down from workman to workman, generation to generation. Many attempts have been made to quicken the liming process by the use of caustic soda and with considerable success. Open cooking with circulating water has come into partial use only. Clarification by means of centrifugals has displaced filtration methods to some extent. The greatest improvement has come in the mechanical handling of jellies by means of the belt-chilling system, which has displaced the old jelly pans all but universally. Much attention has been given to improvements in drying methods, but trouble is still experienced in most tunnel systems during warm, humid weather.

The slow evolution of byproducts manufacture in the animal industry is well illustrated in the handling of bones. At first these, together with other raw materials of the fertilizer industry, were sold at a low price to neighbor firms which worked up the byproducts of the packinghouses, at that time concerned primarily with dressed live stock and cured meats. Next the bones, after first being boiled in open vats for tallow or oil, were dried and ground into raw bone meal and sold for fertilizer.

It was considered a great step in advance when the same bones were steamed for glue and the dried residues sold for fertilizer as "steam bone meal." This product, following the conservation movement of the day, was later worked into animal and chicken feeds. Today some of the large establishments are just beginning to realize that bones are capable of yielding still higher values as gelatine stock. The foregoing refers to ordinary bones. The stronger and heavier bones have always been worked into knife handles, buttons and other objects.

There is much room for improvement in the matter of standards for glue and the methods of arriving at these standards. Although some attempts have been made to put glue testing on a scientific basis, little headway has been made and reference is still had to arbitrary standards. The viscosity determination has been improved and may be said to be on a reasonably satisfactory basis at the present time. On the other hand, the determination of jelly strength is not on a satisfactory basis and there is no agreement among manufacturers and users as to the method to be used. Several types of mechanical devices are installed in different glue laboratories and in others the antiquated, uncertain finger test is still supreme. Its advocates claim that it is more certain and reliable in the hands of an expert than any mechanical device, which is far from the truth. Reform in these matters must come in the future by general agreement among manufacturers and users.

Research

The greatest need of the animal products industry today is the establishment of large, thoroughly organized and well-equipped modern research laboratories. They should be entirely separated from the usual routine analytical laboratories and should have on their staffs the best available experts in the various branches. Without these, progress in the new sense cannot be made and the industry will move ahead by inches where it should go forward by miles. Fortunately, the progressive heads of the large establishments are seeing this need and it may be confidently hoped that in the very near future research in the best sense will be in the hands of an adequate personnel and backed by ample funds. It is hardly necessary to state that research will be applied in the main to the byproducts of the industry. The principal branches of the business are already on an eminently satisfactory and efficient basis.

Changes in the American Diet

Whether it is because of the increased cost of meat or because people's tastes have changed, the fact remains that Americans are eating 8 per cent less meat than they were twenty years ago. This is disclosed in a recent dietary survey made by the United States Department of Agriculture. In this survey 2,000 dietary records, each covering a period of seven days, were collected from 1,425 families and 575 institutions in forty-six states. Sixteen nationalities and many occupations and incomes were represented, as were also both urban and rural localities.

From a summary of 500 of these family records it appears that last year the average cost of food per man per day was 46c., with an average return in food value of 3,225 calories, 96 grams protein, 118 grams fat and 405 grams carbohydrate. These figures are in fairly close accord with the dietary standards ordinarily used in discussing such problems of general nutrition.

A comparison of the foodstuffs purchased by the 500 families with the amounts of the same food purchased by 400 families about twenty years ago shows that the amount of meat in the American diet has decreased about 8 per cent and the amount of grain products about 11 per cent. People are eating more milk, butter and cheese than they were two decades ago, for the amount of dairy products consumed has increased about 6 per cent. Four per cent more vegetables and 8 per cent more fruit are being eaten now.

Some individual food habits undoubtedly need to be corrected, but, judging by these studies, it seems fair to conclude that the average diet seems to be adequate. (*Pure Products*, vol. 16, No. 6, 1920, p. 308.)

Artificial Leather and Coated Fabrics

A Succinct Review of the Development of the Artificial Leather and Coated Fabrics Industries and of the More Important Steps Involved in the Manufacturing Processes Employed, With Special Reference to the Use of Pyroxylin Solution Coatings

ARTIFICIAL leather is a loose term more generally applied to any composite material made up of a base such as cloth, felt or paper, upon which is spread a coating embossed in imitation of grain leather. A very satisfactory product was obtained by coating split leather with pyroxylin. This led to the substitution of fabric for the leather, and thus began a large and growing industry. Stevens first suggested the use of amyl acetate as a solvent for pyroxylin, creating the pyroxylin lacquer industry; in 1884 Wilson and Story first coated cloth with a pyroxylin-amyl acetate solution with which was combined castor oil, the forerunner of the formulas in use today in the manufacture of artificial leather. Subsequent improvement in the latter product has been dependent upon the development of more satisfactory and cheaper solvent formulas, mostly discovered by rule-of-thumb experiment, and also through the use of a better quality of nitrocellulose.

As the result of improved methods for the purification and the nitration of cellulose, a product is obtained which, when combined with a suitable solvent, produces a "dope" which can be readily applied to the base and upon evaporation of the solvent becomes a tough, elastic and durable film.

The Base Material

Little if any change has been made in the base material; the ordinary weaves of cotton cloth have not been improved upon. Cotton cloths, such as sheetings, ducks, sateens and the heavier mole-skins, do not possess an equal stretch in all directions. The strength of the coated fabric on the bias of the weave is somewhat dependent upon the toughness of the film, and in the present state of the art toughness of the film is, unfortunately, gained at the expense of pliability. Even should an improved film be developed, the unequal stretch of the base fabric would remain; a more suitable base fabric would, therefore, considerably improve the quality of the product. For many uses the unequal stretch of the fabric is immaterial; for certain uses the base may be composed of paper, felt or other substance.

For automobile tops the coating is more often composed of rubber, or rubber substitute, or of boiled linseed or other oil combined with pigments. These are not usually termed by the trade as an artificial leather; they constitute, however, a very large class of coated fabrics.

The factors that control the physical and the chemical characteristics of nitrated cellulose are sufficiently well understood, and it is possible to obtain a product which is fairly satisfactory. Nevertheless certain qualities of the pyroxylin are still largely dependent upon the source from which the cellulose is obtained; the fibers from the seeds and the hulls of cotton are considered the most satisfactory. It is possible to purify and to nitrate wood pulp or other cellulose substance, but it is difficult to obtain uniformity of product. At the present price of wood pulp, cotton linters and hull shavings it is a question whether any real economy would result from the substitution of wood pulp. Uniformity of product is essential. A fairly complete dehydration of the nitrocellulose is also essential, and it is therefore necessary that the nitrocellulose be insoluble in ethyl alcohol, as in the most satisfactory method of dehydration the water is displaced by alcohol.

Manufacture of Pyroxylin-Coated Fabrics

The manufacture of pyroxylin-coated fabrics is not a complicated process. The more important steps are: Solution of the nitrocellulose in a solvent; incorporating oil and pigment with this solution; spreading the mixture on the fabric or other base material; evaporation of the solvent; recovery of the solvent (this step is not essential); embossing the coated fabric.

Cotton cloth is generally used as a base. This must be free from imperfections of weave and must be made from uniform yarn, as loose or heavy threads will show in the finished product. Light-weight fabrics, such as sheetings, are usually sized; heavy-weight fabrics are teased to raise the nap. The cloth is usually dyed in order to prevent any discoloration of the back becoming apparent should the coating come through the cloth. In the light-weight fabrics this is largely prevented by the sizing, the primary object of which is to stiffen and weight the goods. Raising the nap on the heavier weaves assists in producing a firm anchorage of the coating to the cloth. For certain uses, such as wall coverings, paper may be used as a base; felt, or fabric made from other material than cotton, may be coated successfully.

Solvent Formulas Secret

Many solvents and combinations of solvents have been used; it is to the development of improved or less expensive solvent formulas that the expansion of the industry has been largely due. For this reason the manufacturers of artificial leather keep their formulas secret. Patent literature is replete with solvent and "dope" formulas, but it is quite certain from commercial considerations that but few solvents are being used. The manufacture of artificial leather is a highly competitive business; for this reason the solvents selected are restricted to those that can be obtained cheaply. Ethyl alcohol is relied upon in the dehydration of the nitrocellulose and is an incidental constituent of most solvent formulas, but other aliphatic alcohols could be used. On the other hand, alcohol is not an essential constituent. Amyl acetate is now largely replaced by the cheaper ethyl acetate; this is diluted with benzol or other hydrocarbon of the benzol series. Benzene or gasolene is a constituent of some formulas. The pyroxylin solution must be clear, free from dirt and undissolved nitrocellulose, and as near as possible of a standard viscosity. The solution will contain from 75 to 90 per

cent solvent. If such a solution were used to produce a heavy film, the finished product would be stiff. In order to obtain pliability an oil is mixed with the pyroxylin solution, and to this mixture may be added pigments ground in oil to produce a colored coating.

Oils Used to Give Pliability

Various oils may be used to give pliability to the film. Castor oil was first used, and no satisfactory substitute has been found where a light-colored coating is required. This oil has, however, an objectionable odor which is noticeable in the finished product. Other oil may be substituted for castor, such as blown linseed, rapeseed or cottonseed, or a mixture of these; and other non-drying or semi-drying oils have been used. Blown oils are dark in color and therefore cannot be used with the lighter colored pigments. Another source of trouble is the likelihood of the commonly used oils becoming rancid if the finished product is stored for any considerable time. A cheap, non-drying oil that is light in color and one that would not develop rancidity would fill a long-felt want in the industry. Standard pigments ground in oil are used to give color to the coating. The less expensive pigments are chosen. Except for light-weight coatings over a non-dyed base material it is not necessary that the pigment possess great covering power.

The Coating

The coating on a piece of artificial leather is built up of a number of thin coats, all of which do not have the same composition. Upon light-weight fabrics as few as three coats may be applied, while to produce an imitation of heavy Spanish leather, such as is used for upholstery, twenty-five to thirty or even more coats may be necessary. The first two coats are depended upon to give anchorage; these are of special composition and usually contain less oil and pigment than the succeeding coats. The top coats give the finish to the product, and take all the wear. These are applied thinly, except on very light-weight goods; usually the top contains neither oil nor pigment. Exceptions would be the imitation Spanish and Morocco leathers, to which are applied an elaborate hand finish; or, in cheaper grades, machine finish.

Individual coats are applied, drawing the base material under a knife-edge, the "dope" being run onto the material in front of the knife-edge as fast as it is used. This operation is performed by machines. By paying attention to such details as the design of the knife-edge, the tension applied to the base material and the viscosity of the pyroxylin solution, it is possible to control the weight of each coat. In the present state of the art the quality of the product is improved by increasing the number of coats for a given weight of coating. This adds to the cost of production. Here is a very promising field for development. Considerable ingenuity and a large amount of capital have been expended in attempting to solve the problem, so far without marked success.

Between individual coats the solvent is evaporated from the film more or less completely. Often some solvent is retained in the finished piece to give additional pliability, and a high boiling point solvent may be added for this purpose. This is not, however, a satisfactory method of obtaining pliability; in the first place, it is more expensive than other methods that may be used; in the second place, such solvent ultimately evaporates from the coating and thus defeats the purpose for which it was added. If an attempt be made to recover the solvent, that added for this purpose is an unnecessary loss.

Recovery of Solvent a Subject for Development

It is still a moot question as to whether the solvent which must be evaporated from the coating should be recovered or not, the claim being made that a better quality product can be produced without solvent recovery. For theoretical reasons the reverse should be true. With a properly designed recovery apparatus it is possible to control drying conditions and in this way produce a more uniform film. If from 80 to 90 per cent of the solvent can be recovered, there is no question that recovery is economical. With the probability of increasing prices for solvents, the manufacturer with efficient solvent recovery apparatus has a decided advantage, both as to costs and quality. The problem of putting the recovered solvent into suitable condition for re-use is not difficult. There is an opportunity for considerable development along these lines.

Embossing to Imitate Grain Leather

The coated material from which all or at least a large proportion of the solvent has been removed is embossed in plate or rotary presses to get an imitation of grain leather. The heavier grades are preferably embossed on plate presses, as these are likely to roll-cut, and deep embossing is to be avoided. Imitation Spanish and Morocco leathers are hand-finished to give the impression of age to the product. To obtain this appearance a light deposit of a pigment darker in color than the coating is spread over the embossed piece of goods. This pigment is rubbed off of the high spots into the valleys of the embossing by means of a pad soaked in a solvent that softens the film slightly, anchoring the pigment onto the coating.

Two Problems Awaiting Solution

Two problems of utmost importance in the artificial leather industry are awaiting satisfactory solution. The first is the production of a durable film with fewer number of coats and the second has to do with the recovery of solvents. These apply to pyroxylin-coated fabrics. As has been pointed out, the base fabrics in use are not as satisfactory as could be desired. It is quite probable that the market for coated materials can be further developed, with improvement in durability and reduction in costs.

Recent Patents on Artificial Leather

Among the quite recent patents on the manufacture of artificial leather may be mentioned the United States patent No. 1,337,802 and the German patent No. 302,445.

The American patent, by Albert E. Somerville, consists in winding into a roll a vulcanizable rubber layer and sheet of paper in intimate surface contact with each other, subjecting this roll to the action of the vulcanizing medium, and removing the paper sheet, thereby providing a material having the characteristics of dull finished leather.

The German patent, by E. Reidel, consists of treating dried animal intestines, sinews and the like with acetic acid or sodium sulphide. The product is washed, compressed between rollers, dried and saturated with a solution of albumin and a marine animal oil. The product, after compression to sheets, is dried and tanned by the combined mineral and vegetable process.

(Photo by J. W. Hess, Pueblo)

A VIEW IN THE DEBEQUE, COL., OIL SHALE REGION

The Necessity for Research in the Oil-Shale Industry

An Account of the Shale-Oil Industry as Developed in Scotland—Steam-Regulated Pyrolytic Distillation—Quality and Quantity of Oil Yields—New and Improved Practice Should Be Developed From Old Operation

BY MARTIN J. GAVIN*

ONE rarely reads a technical or oil-trade journal without coming across some article or statement regarding oil shale. We are told of the enormous supplies of this material within the borders of the United States, of the plants to treat shale that are operating or under construction or about to be constructed, of the companies organized to produce and refine oil and other products from oil shale, and commonly of the huge profits to be made on small investments in oil-shale operations. Supplementing these articles, the country has been well covered with oil-shale company promotion literature, commonly of a still more optimistic and often misleading nature. The public apparently has been led to believe that the American oil-shale industry is a going one—that is, plants are making and refining shale oil on a successful commercial scale—and that money is actually being made in oil-shale operations by marketing shale oil and its products.

SHALE-OIL INDUSTRY ACTIVITY

The writer does not desire to discourage the proper kind of activity in connection with oil shale, because the time is growing near when shale-oil products will undoubtedly be necessary to supplant in part our present petroleum supplies, and he believes that in the course of a comparatively short time oil-shale operations, if properly conducted and financed, can be made commercially successful. It is desired in this paper to indicate particularly the great necessity of properly conducted scientific research and control work on oil shale and shale oils, without which it would be indeed difficult to carry on oil-shale operations successfully.

At the present time there are, strictly speaking, no commercial oil-shale operations under way in the United States. There have been perhaps eighteen or twenty shale retorts erected in the country and most are in intermittent operation from time to time for experimental or demonstration purposes, but with one or two possible exceptions these are too small to give much of an idea of their commercial feasibility. Nearly if not quite 150 companies have been organized in connection with oil shale, many of which, unfortunately, are purely stock promotion concerns. Some are actually engaged in experimental work of a sort, and a very few are actually conducting well-planned and organized investigational and research work.

GREATER CO-OPERATION AMONG INVESTIGATORS NEEDED

There is very seldom a laboratory at the experimental plants, and only infrequently a well-trained technical employee. Except in a very few cases, shale oils produced in the small plants have never been given more than very superficial inspection and the real quality of the oil made is generally unknown even to the operators themselves. There is little spirit of co-operation among the oil-shale operators, each apparently believing his idea of a shale retort to be far superior to all others. In passing, the writer expresses as his opinion that mutual helpfulness and co-operation will go a long way in the building of a successful oil-shale industry in this country, as there is so much work to be done and so many problems to be solved that no one individual or company can hope to do it all.

NOT ENOUGH CONTINUOUS EXPERIMENTAL WORK

Experimental work in connection with oil shale, again, with one or two notable exceptions, has so far consisted in the construction of a retort, usually designed along lines as different as possible from the well-known Scotch type of retort, and its operation at maximum capacity until a certain lot is run through; then it is shut down until another lot is ready for testing.

Rarely is attention paid to the quality of oil produced. As far as the writer knows, none of the plants has been operated long enough or under such conditions as would

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give an idea of its life in commercial practice. A run is usually considered successful if oil is produced and the residual shale yields practically no more oil. There are practically no recognized retorting methods and usually, in any particular type of retort, all shales are treated under the same more or less accidental conditions.

As a rule the retorts are designed with the idea of removing oil vapors from the retort as soon as they are formed, but this idea is not always carried out. Most retorts builders try to get as far away from Scotch practice as possible and though many use steam in retorting, the quantity used is so small or it is applied under such conditions that it gives negligible results.

The Scotch Practice

For a proper understanding of problems in shale-oil production and refining, it is desirable that Scotch practice in this regard be outlined, as it is generally not well known, or its principles are misinterpreted.

In the following discussion the writer wishes it to be understood that he does not believe Scotch oil-shale retorts and operations to be the last word in the oil-shale industry. It is reasonable to believe that types of retorts and practices different from those employed in Scotland may be developed in this country more particularly adapted to American shales and conditions. It is emphasized, however, that the Scotch oil-shale industry is really the only commercially successful oil-shale industry in the world at the present time and that it has been successful for more than sixty years. This being the case, the logical first step in the development of an oil-shale industry in the United States, a new art here, would be an attempt to apply the apparatus and practices now used in the country where oil-shale operators have reached their highest development. If Scotch methods are not found satisfactory in this country, it may be possible to modify them, and even if modifications are unsuccessful, the knowledge of Scotch shale operators, based on over sixty years of practical experience, cannot reasonably be disregarded but logically should serve as points of reference.

In Scotland the shale brought from the mine is crushed by toothed rolls into pieces of average size of an ordinary brick; as a rule everything going through the rolls goes to the retort.

Scotch Retorts

From the breakers the shale is carried in cars up an incline to the top of the retorts, where it is dumped into the retort hoppers by hand. The most commonly used Scotch retorts are vertical and tapered, consisting of the following parts: At the top there is a hopper, which holds several hours supply of shale. Below the hopper is a cast-iron upper part which is about 12 ft. in length and which has a vapor outlet near the top. Under the cast-iron part, and joined to it with a fire-clay joint, is the lower masonry part, which is about 18 ft. high and made of a single tier of very special-shaped firebrick. At the bottom of this part is the discharge mechanism and below that the spent-shale hopper, which serves one or two retorts and in which the spent shale accumulates. The cast-iron part is made circular or elliptical in cross-section, and the masonry part square or circular. Those of circular cross-section have an internal diameter of about 2 ft. at the top and 3 ft. at the bottom. The taper is constant.

Each retort, with its supply hopper, holds about nine tons of shale and the feed is by gravity. Four retorts, as described, are set in a common furnace and are heated by the combustion of the fixed gases resulting from the distillation of the shale, supplemented by coal producer gas when necessary. Four retorts are a unit, and sixteen such units constitute a bench, two retorts wide and thirty-two retorts long. The present retort working on shale now being mined in Scotland has a capacity of about four and one-half short tons per day. Tests indicate that the retort capacity is a function of oil production rather than shale throughput. Apparently a Scotch retort will produce approximately 100 gal. of oil a day, whether it is working on a 10-gal. shale or 100-gal. shale. In the former case approximately ten tons can be put through; in the latter but one.

In the upper or cast-iron part of the retort most of the oil distills and the maximum temperature in this part does not exceed 900 deg. F. The lower or masonry part serves mainly as an ammonia and gas producer. About 105 gal. of water, as exhaust steam, for each 25 gal. of oil produced is admitted into the spent-shale hopper and passes up through the shale in the retort. The steam serves to absorb the heat from the spent shale, to produce water gas from the fixed carbon remaining in the spent shale, to distribute evenly the heat in the retort, to produce ammonia from the nitrogen of the shale, and to carry off the oil products formed. Distillation with steam increases the yield of ammonia about two and one-half times as compared with dry distillation, and also produces more oil which is of higher quality.

Temperature and Heats

The maximum temperature to which the shale is subjected it not much in excess of 1,500 deg. F., although temperature measurements have never been accurately made within the retort itself. The retort operators are skilled in judging retort temperatures by heat colors, and keep temperatures under careful control by looking into the furnace through peepholes. In general, in retorting and refining practice in Scotland, one is struck with the very definite way conditions are controlled. Many years of practical experience have determined these conditions.

The spent shale is discharged continuously from the retorts and the mechanisms used for this purpose constitute the main points of difference between the types of retorts. The spent shale is refuse. No commercial use has ever been found for it, although it has been tried in road and brick making. The fixed carbon remaining in the shale amounts to only 1½ to 2 per cent. This is the economic limit with reference to fuel consumption, throughput of shale, and ammonia and gas yield. A greater yield of ammonia could be obtained by reducing the amount of carbon, but at the expense of throughput.

Vapors Separated From Gases and Refined

Vapors pass out of the retort through the vapor line, which is cast integral with the upper part of the retort. Large suction fans in the dry gas main, between the scrubbers and gas burners, put a slight suction on the retorts. The vapors pass to large headers and thence to a series of U-shaped, vertical, air-cooled condensers made of cast-iron pipe. Below each U is a

receiving box for condensate, and from this box the condensed oil and ammonia water are drawn off to separating tanks. Uncondensed gases pass through water scrubbers, which remove any ammonia remaining in the permanent gases, and through oil scrubbers, which remove the light hydrocarbons, commonly known as "scrubber naphtha." The gas is then led back to the retort furnaces, where it is burned.

Shale now being worked in Scotland yields per short ton approximately 10,000 cu.ft. of gas having a heat value of about 240 B.t.u. per 1,000 cu.ft., approximately 24.5 U. S. gal. of crude oil and 36 lb. of ammonium sulphate.

The crude oil, after having the bulk of the water separated, is run to the refinery. The refining of this oil is more involved and complicated than the refining of petroleum, as the oil must be subjected to more acid and alkali treatments and a greater number of distillations. Therefore a shale-oil refinery contains more small stills and agitators than does a petroleum refinery of equal capacity. More batch stills are used than continuous stills, and the Scotch shale-oil refineries have extraordinarily large wax plants compared with petroleum refineries of equal capacity.

Flow Sheet of Products and Plant Layout

Practically all refinery distillations are conducted with a large quantity of steam, which is admitted into the bottoms of the stills. The crude oil is run to coke, as are also some of the redistilled oils.

The yield of refined products in Scotland is somewhat as follows:

	Per Cent
Naphtha (including scrubber naphtha) 450 deg. end point	9.9
Burning oils (kerosene and the like)	24.7
Gas and fuel oils	24.4
Lubricating oils	6.7
Wax	9.5
Still coke	2.0
Loss	22.8
	100.0

A general idea of the complexity of shale-oil refining in Scotland can be gained by referring to Fig. 1, a generalized flow sheet of refinery operations at a typical Scotch shale works. This figure and Fig. 3 are presented through the courtesy of Scottish Oils, Ltd. The writer wishes to express his appreciation particularly to H. R. J. Conacher of this organization for the use of these figures.

Scrubber naphtha, which is the gasoline or naphtha recovered from the retort gases by washing them with oil and subsequently distilling the latter, amounts roughly to 2.4 gal. per ton of shale.

Ammonia water from condensers and scrubbers is run to ordinary continuous ammonia stills. Ammonia gases pass off and are dissolved in dilute sulphuric acid, much of which is recovered from the acid tars. The sulphate solution is concentrated by a continuous system and is finally purified and sold as crystalline ammonium sulphate.

Fig. 2 is a plan of a typical modern Scotch oil-shale works, including retorting plant, oil refinery and ammonium sulphate plant, with accessories. It serves to indicate the outlay and equipment necessary in the production and marketing of refined oil-shale products, and gives an idea of the scale under which Scotch operations are carried on. Such a plant represents the investment of several millions of dollars.

The principal objection in the minds of American shale operators to the Scotch retort is its low throughput and its use of steam. Scotch operators find that it is necessary to heat their shale slowly and to use plenty of steam if a satisfactory oil is to be produced, and the past tendency in Scotch practice has been to lengthen the time of treatment and use more and more steam. As a matter of fact, the amount of steam used is largely determined by the amount of oil a shale will yield. Rapid production of oil from Scotch shale has meant that an oil of poor quality resulted, though not enough work has been done on American shales to determine if they will behave the same way.

The use of steam in retorting apparently does so much more than merely produce ammonia that its use cannot be abandoned without further consideration even if ammonia recovery is not desired. The spent shale coming from the Scotch retorts is very hot (perhaps 1,500 deg. F.) and if not steamed would be discharged

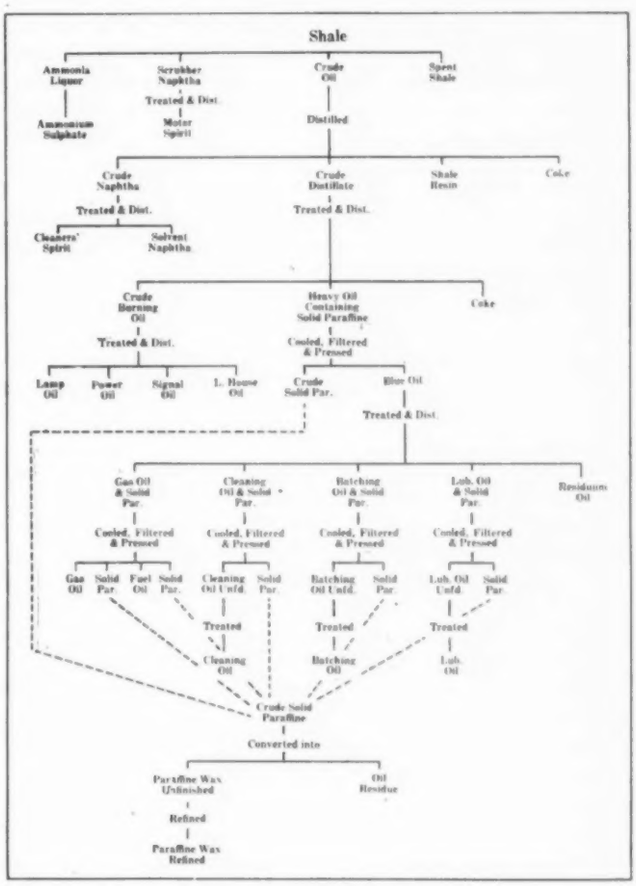


FIG. 1. FLOW SHEET OF SCOTCH REFINERY OPERATIONS

in that condition and contain from 6 to 10 per cent of fixed carbon the fuel value of which would be wasted. The use of steam, as described, cools the shale, while heating the steam, thus carrying heat back into the retort; in addition, the steam and fixed carbon in the shale react, producing a gas of good fuel value, since it is composed mostly of hydrogen and carbon monoxide, thus utilizing much of the fuel value of the fixed carbon in the spent shale. As the carbon is burned out, ammonia is produced, and the excess steam and other gases protect the ammonia from decomposition at the high retort temperatures, and sweep it at once into the cooler zone. Oil production in the upper part of the retort goes on slowly and oil vapors made are at

once swept away to a cooler zone and out of the retort by the excess steam and gas, thus effectively protecting the oil from excessive decomposition.

Byproduct Ammonia

The question of producing ammonia from oil shale is one that has been discussed at considerable length by those interested in oil shale in this country. The average American oil shale compares favorably with Scotch shale in nitrogen content and it is to be expected that the nitrogen in both shales can be recovered with equal ease. The general tendency among American oil-shale processes seems to disregard ammonia recovery except the small amounts incidentally produced in ordinary dry destructive distillation. It is felt by many that the conversion of the nitrogen in a rich oil-yielding shale into ammonia is not a desirable thing, as such conversion would reduce the retort capacity for oil. While this is probably the case, there is nevertheless a fair probability that the increased returns made by producing ammonia would more than counterbalance the decreased oil-producing capacity of the retort, assuming a satisfactory market for the ammonia exists. This may particularly apply if it is found that steaming the retorts is necessary to produce the best grade of oil. To produce maximum economic yields of ammonia from oil shale, Scotch operators find a maximum temperature of about 1,500 deg. F. and an excess of steam necessary. While 900 to 1,000 deg. seems to be the highest temperature necessary to produce oil from oil shale, the increased heat needed to produce the ammonia is nearly if not completely supplied by the combustion of the gas produced by the action of steam on the carbon of the shale in the ammonia-production part of the retort.

The use of steam in retorting is said by the Scotch operators to increase the yield of ammonia over two and one-half times the amount recovered by straight dry destructive distillation. In discussing the ammonia-recovery problem, it is necessary to point out the possibility of recovering part or all the nitrogen of the shales in some form other than ammonia, such as pyridine compounds and the like, and also the conducting of the oil-recovery and nitrogen-recovery operations in separate and more or less independent apparatus. Both of these possibilities require thorough study, and whatever is done in the way of recovering nitrogen must take into account the main purpose of oil-shale treatment—that is, oil production.

Quality and Quantity of Yield

The writer has examined oils from Scotch plants and oils produced by different processes from various American shales, and has found that the quality of the Scotch oil is in every way much better than any oil he has thus far seen from American shales. Whether this is mostly due to the nature of the processes or to the shales themselves he is not definitely prepared to say, although it is known that the conditions under which oil is produced from shale have a very decided influence on the quality and quantity of oil yield. However, it has also been determined that different shales, retorted under identical conditions, do yield somewhat different oils. Both factors undoubtedly influence the quality of the oils yielded to a considerable extent.

The problem of those working in oil shale seems to be the production and subsequent refining of the best possible quality of shale oil consistent with economic practice. Once these conditions have been determined, they must be controlled and held as uniform as possible in commercial practice. The quality of oil produced will perhaps depend on the kind and amount of products desired, but it seems that the crude oil should be obtained in as undecomposed or uncracked state as possible. This has plainly been the aim of the Scotch operators. Every successful change in Scotch retort design can be noted in the greater production of burning oils and wax from the Scotch crude, a plain indication of less cracking.

Perhaps, in the United States, it may be desired to obtain a greater yield of gasoline or light oils by cracking the crude shale oil. Even then it would appear that the crude should be obtained from the retort in as uncracked a state as possible, and only those fractions of the crude most adapted for cracking be so treated. Cracking the crude itself, either during production or subsequently, can reasonably be expected to yield more light oils, but at the expense of some of the desirable heavy fractions of the crude. The production of a crude yielding a maximum amount of gasoline directly from the retort is thus apt to be a decidedly wasteful and uneconomical practice and moreover likely to yield a very unsatisfactory grade of gasoline, since the cracking of the crude during production cannot be so easily controlled as the cracking of a selected fraction in a separate apparatus designed solely for cracking, where exact control is possible.

As a rule, American shale oils thus far examined differ from the Scotch crude in that the former are heavier (specific gravity 0.900 to 0.980) than the latter (specific gravity 0.875), fractions from the former are more highly unsaturated and the odor more disagreeable than those from the Scotch crude. The American shale oils thus far examined were of a mixed paraffine and asphalt base, while the Scotch oil is distinctly of a paraffine base. It may not be possible to make as good oils from American shales as from Scotch shales, possibly because of the nature of the shales themselves, but undoubtedly better oils can be made than are being produced here today once the proper study of retorting methods has been conducted.

Oil production from oil shale is a process of destructive distillation which is not a haphazard affair, but one which must be properly controlled if good results are to be obtained. Obviously there are certain factors influencing oil production from shale, and for any shale the proper thing to do is to determine optimum conditions for producing an oil which will yield the greatest profit.

Factors Influencing Yields

The Bureau of Mines, in co-operation with the State of Colorado, is investigating certain of these factors in its investigation at Boulder, Col., on Colorado oil shales, with the idea that best conditions, as determined from small-scale experiments, will later be applied commercially in so far as commercial considerations permit. Some of the factors which can be expected to influence oil yield and quality, and the influence of which should be studied, are set forth below.

a. Size of shale particles treated.

b. Thickness of charge in the retort.

c. Rate of rise of temperature of the charge.

d. Maximum temperature to which shale is submitted.

e. Time of contact with and maximum temperature to which vapors are submitted.

f. Effect of steam and other vapors and gases.

g. Pressure under which retorting takes place.

If greatest economic returns are to be obtained from oil-shale operations, the effect of such factors as these should be determined.

Figs. 3 and 4 show, respectively, the retorting and laboratory equipment established at Boulder in connection with the above-mentioned investigation.

The Shale Oils

Once the oil is produced, it must be studied to determine its refinability. The high refining loss incurred in Scotch operations has been noted, and efforts should be made, of course, to keep this figure to a minimum in the refining process. New processes of refining and treating may be worked out when the oils produced are thoroughly studied and tried out in commercial operations. The Bureau of Mines, at its Salt Lake City Station, in co-operation with the State of Utah, is studying the oils produced from various shales and by various processes, correlating its work in this regard with the co-operative work in Colorado.

All American shale oils thus far studied by the Bureau are highly unsaturated and contain a considerable amount of nitrogen bases. Some of the unsaturated compounds can probably be allowed to remain in the finished products, but others polymerize and deposit gums and resins which must be removed in refining. The use of steam in Scotch retorts seems to prevent the occurrence of nitrogen bases in the oil to a large extent. It seems that ordinary methods of refining petroleum will have to be modified for shale oil, and such modification can be the result only of thorough study of the oils themselves.

Particular attention is directed to the high loss incurred in refining Scotch shale oil. The refining loss, as has been noted, amounts to about 23 per cent of the crude treated. Thus, although average Scotch shale yields about 24.5 gal. of crude oil to the ton, only about 20 gal. of this is marketed. As compared with this high loss, the average loss in straight run refining of petroleum in American practice does not exceed 3½ or 4 per cent. If the shale oils thus far examined by the Bureau of Mines are a fair indication of what can be expected from American shales in commercial operations, apparently the loss in refining them by Scotch methods would amount to nearly twice the loss in refining Scotch shale oils. If ordinary petroleum-refining methods are used, probably the loss would be still larger.

Oils are refined for the purpose of making marketable products from them. In refining operations undesirable or offensive substances are removed from the oils in order to make the finished products acceptable to the consumer, but in refining oils which suffer high refining losses, such as shale oils, it is probable that not only are objectionable substances removed but a considerable amount of material which might be retained in the finished products to good advantage.

Therefore probably a major problem in shale-oil refining is the reduction of refining losses, either by the development of new or modification of old methods. Such development or modification can come only as the result of technical study of the oils.

A refinery loss is a loss from more than one standpoint. In the first place, there is an actual loss of material, and in the second, treatments in which losses are incurred are more or less expensive. So the refiner not only loses a part of his oil but pays for losing it.

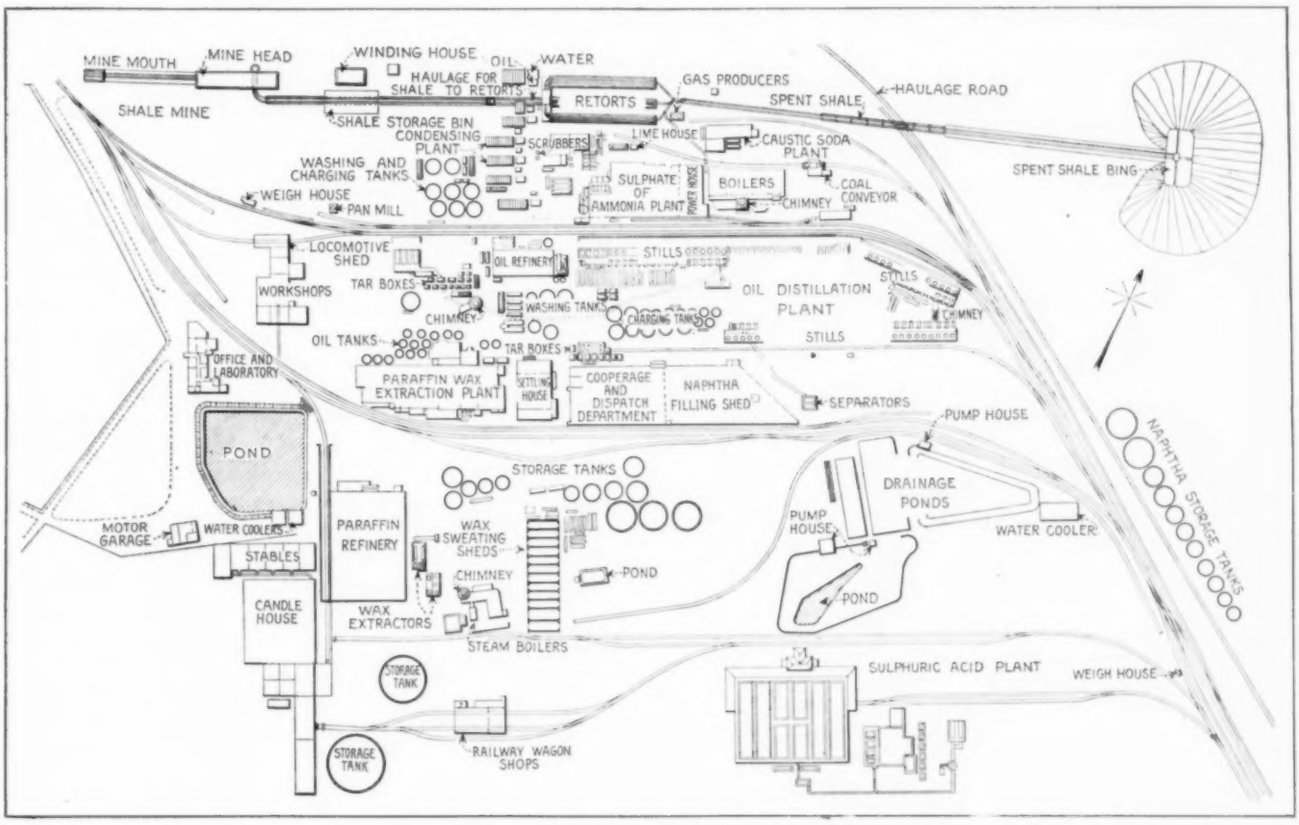


FIG. 2. PLAN OF TYPICAL SCOTCH SHALE WORKS

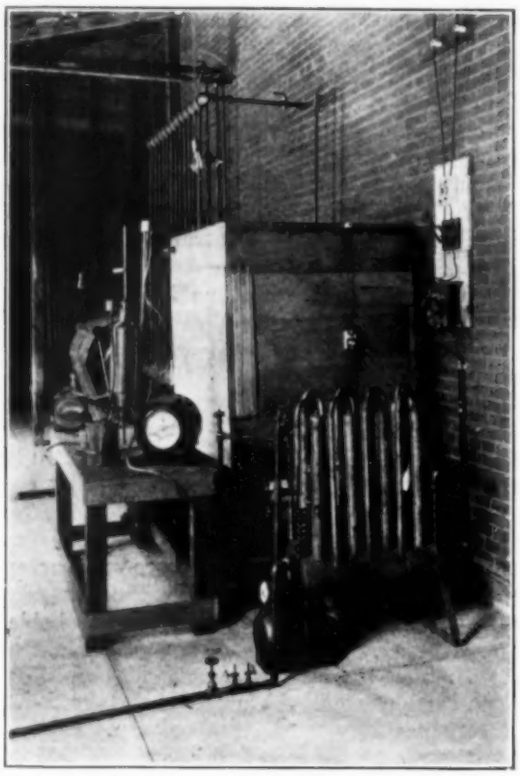


FIG. 3. OIL-SHALE RETORTING EQUIPMENT AT BOULDER, COL.

A large part of the refining loss in any event will probably be in the form of acid and alkali tars, and a field of research to utilize these tars is plainly indicated.

This discussion is intended to call attention to the fact that conditions of retorting and refining should be worked out on a scientific basis if maximum returns are to be expected in oil-shale operations. Each operator should know with scientific accuracy the optimum conditions for treating his shale and refining his oil. The chemist and chemical engineer will probably have a greater field for research in oil-shale operations than in petroleum production and refining. Particularly the oils need study. It is not possible to predict with accuracy the possible profits a plant can expect, or its costs, until the quality and quantity of products of marketable value it can make are known, as well as the conditions under which they can be made and refined.

When the problem of producing satisfactory products has been solved, there may be a field for research in the study and production of byproducts. Discussion of byproducts seems premature now, it is true, but later the oil-shale industry may develop an important byproduct industry. As a matter of fact, few realize the importance of the present petroleum byproduct industry.

When the Scottish oil-shale industry was started, economic conditions were such that the oils produced could be marketed with profit, but these conditions have changed, and since about 1864 the industry has been successful only because of continual improvements that have been made in the technology of shale-oil production and refining. In this regard, Steuart[1] writes:

"The Torbanehill mineral[2] yielded the raw material for about a dozen years, much of it being used in Scotland and some being exported to America and the Continent for distillation.

"In 1862, the supply from this source was being exhausted, and the material became too valuable and expensive for this industry, hence shale was resorted to, but with widely different results. While the Torbanehill mineral yielded about 120 gal. of crude oil per ton, the shales first used furnished 40 to 50 gal. and soon the yield was 30 to 35 gal. The expiry of Young's patent in 1864 led to a rapid expansion of the Scottish oil industry, but ere long it sustained a severe check. The discovery in 1859 of oil wells in Pennsylvania by E. L. Drake was soon followed by the importation of petroleum lamp oil into Britain, the quantity increasing year by year. Owing partly to this competition and partly to the increase in the number of oil works, prices gradually fell. . . .

American and Russian Competition

"At first the Americans exported to Britain only burning oil, but they soon began to introduce supplies of lubricating oil and subsequently of solid paraffine. Then the smaller works (whose retorts had been mostly for the production of burning oil) tended to decrease in number, and the larger ones to increase in size, thus concentrating and cheapening production. Retorts were improved to suit the circumstances, and to produce a purer oil with a larger proportion of heavy products. Mechanical labor-saving arrangements were devised, refining was improved and cheapened, and economies of every kind were introduced. The chemicals used in refining were recovered; and the tars separated by them, the removal of which had involved expense, now became a source of profit as fuel. The supply of Peruvian guano began to fail, hence the price of sulphate of ammonia rose to £22 (1880) and even to £24 per ton; but as the importation of nitrate of soda increased greatly, it fell below £8 per ton about 1890, when burning oil sold at less than 6d. per gal. These conditions led to further concentration. Retorts especially designed for the manufacture of sulphate of ammonia were universally adopted, and improvements were introduced to secure greater economy of working. With the older type of retorts a shale had to yield about 30 gal. of crude oil per ton in order to be profitable; but with the new retorts, and the increased yield of ammonia and fuel gas, a shale furnishing 20 gal. is remunerative. Not more than 16 lb. of sulphate of ammonia per ton was formerly obtained as a maximum, now 35 to 70 lb. is got, according to the quality of the shale. By these methods the quality of shale that can be worked with profit has been increased and the life of the Scottish industry has been lengthened.

"Since 1873 the Russian petroleum industry has developed rapidly, and in recent years competition from this source has become very severe. Russian crude oil, however, produces no solid paraffine; and America shows signs of not being able to respond as easily as formerly to the increased demands of the world for petroleum, any increase in American output being fuel oil. In 1905, however, it succeeded by great effort in making up for the Russian deficiency caused by troubles at Baku. In 1909 and 1910 there was a definite decrease in the export of burning oil from America to Britain. Sulphate of ammonia is being produced in greater quantities from iron works, coke ovens, Mond gas producers, etc.; but the demand also increases. New competitors are always

[1] Steuart, D. R., "The Oil Shales of the Lothians"—Part III. "The Chemistry of the Oil Shales." "Memoirs of the Geological Survey," Scotland, pp. 137-138.

[2] A very rich oil shale.

arising; recently, for instance, Galicia with solid paraffine, Rumania with burning oil, and the Dutch East Indies with motor spirit. But notwithstanding this prolonged and fierce struggle for existence, the Scottish industry still survives. The Scottish companies vie with one another in their efforts to improve and cheapen the processes, and show signs of mutual helpfulness and co-operation. In the early days of the industry operations were carried on in a simple but expensive fashion. Sometimes the shale was carted miles to the retorts, and the crude oil carted miles to the refinery, and breaking shale, pumping oil, etc., were done by manual labor. But through all these years evolution has been at work in developing a high state of organization, resulting in economy and efficiency. The most of the existing works have adopted electricity for lighting and for the conveyance of power for all purposes.

"In 1894 there were thirteen oil companies in Scotland; now there are only seven (three of which produce crude oil only), but the output has not been reduced."[3]

New and Improved Practice Being Developed

Thus there is seen the continual application of new and improved practice in the Scotch industry, a practical seeking after better methods, perhaps not by means of strictly scientific research, but nevertheless by research, which, conducted in a practical manner and with a definite objective in view, has kept the industry alive. It may be noted that the only companies in Scotland which have survived during the long years of competition have been those which could afford to experiment and had the capital at hand to conduct operations in a large way under the supervision of trained technicians and executives. Once a market had been established for certain products, efforts have continually been made to increase the yield of these products and lower production cost.

The oil-shale industry in this country will afford a field for the mining and mechanical engineer, as well as the chemist and chemical engineer. Mining the shale is bound to furnish a very important item in the total cost of producing refined shale-oil products. In Scotland the cost of mining the shale is well over 50 per cent of the total cost of making refined shale oils. The mining of oil shale in this country should offer the mining engineer an opportunity to devise new methods of drilling, breaking down, hoisting, conveying, crushing and the like, and permit the reduction in total costs by supplementing high priced mine labor with mechanical devices.

Retort Construction

Retort construction is a problem for the mechanical and chemical engineer. The Scotch retort, when carefully examined, is found to be admirably suited for its task. A notable feature in its design is the manner in which provision is made for the expansion and contraction of each retort in a unit, independently of any of the others. The average life of the best types of Scotch retort is well over twelve years; the value of this figure can be appreciated when it is learned that the life of the first retorts used was only one and a half to two years. The mechanical engineer may be asked to adapt the Scotch retort to American shales, and the writer believes it to be capable of considerable modification for certain definite purposes. Its freedom from complicated mechanical devices, long life and satisfactory performance for so many years in Scotland make it difficult to disregard for use in this country without complete trial. A shale retort must be rugged enough to operate continuously for long periods at comparatively high temperatures handling an abrasive material. As has been the case in coal byproducts plants, the engineer may be able to substitute ordinary firebrick with other refractories, such as silica brick, and there may be a new field for the use of alloys and metals with protective coatings designed to resist oxidation at high temperatures. In the refining of the oils it is expected that while much of the ordinary petroleum-refining equipment can be used, probably much of it may have to be modified, and there are distinctly seen the possibilities of new refining processes, equipment for which the chemical and mechanical engineer will be called upon to supply.

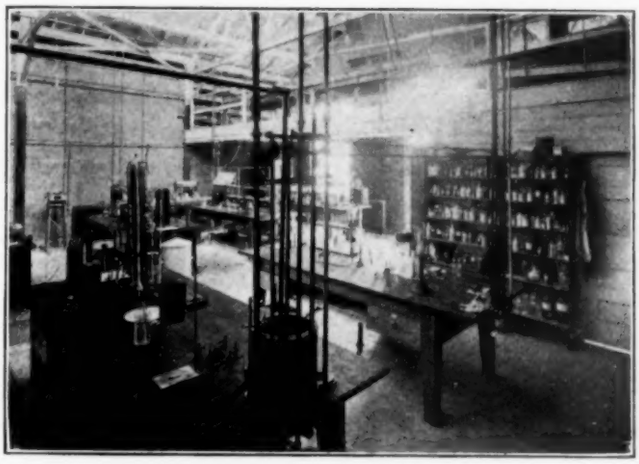


FIG. 4. OIL-SHALE LABORATORY AT BOULDER, COL.

Success Ahead

The future of an oil-shale industry in this country is practically assured by the increasing consumption of petroleum and its products in this country over domestic production of petroleum. Indications are that in the comparatively near future the United States must import the bulk of its petroleum or find a substitute or new source of hydrocarbon oils. While possibilities in the use of such substitutes as alcohol and coal-tar products cannot be disregarded, the writer sees in oil shale the natural and logical source of oils to make up in large part the coming deficit between domestic consumption and production of natural petroleum. It seems certain that motor fuels, burning oils, fuel oils and paraffine wax can be made from shale oil, but there is considerable doubt as to the possibility of producing more than moderately viscous lubricating oils from them. Between the knowledge that certain oils can be produced and their actual commercial production is a large gap which must be filled by properly directed research and investigational work. There are reasons to believe that a company, well organized, with plenty of capital and well equipped with business and technical men, if situated favorably, would have a reasonable chance of establishing successful commercial shale-oil production, if not at the present time, at least in the near future. The necessity for technical investigations and control, however, cannot be too strongly emphasized, because the oil-shale industry, in its final analysis, is nothing but a low-grade raw material chemical manufacturing enterprise, which, when economic conditions are right, depends on capital and business and technical ability for success.

[3]The largest of these consolidated into one company, Scottish Oils, Ltd., in 1919.—Author.

AN INDUSTRIAL RESEARCH LABORATORY DEVELOPED FROM AN OLD MILL IN A FAVORABLE LOCATION

A Novel Laboratory for Industrial Research

A Description of a Research Laboratory Organized to Study and Develop New and Economical Problems Relating to Chemical and Metallurgical Processes and Equipment, With a Succinct Enumeration of Some of the Problems Which Are Being Studied

WE HAVE been preaching the doctrine of intelligent research in industry so earnestly that it is always a pleasure to tell of the successful operation of a laboratory devoted to the purpose. Of course, a laboratory is only a shell; it is the men in it that count; but wisdom begins in regard to this subject with the selection of the men, the selection of the subjects for research and the establishment of proper facilities and surroundings for the work. Certain principles seem to be pretty well established: The men engaged in research must not be taken from their work to do incidental testing for production control; they must not be teased and hectored by problems of administration; their business is abstract thinking and corroborative testing, and these things are incompatible with union hours, the time clock or the whistle.

In a way, of course, research is speculative, but the word needs qualification. Anybody with money in the bank can speculate if he wants to but the number of persons who can engage successfully in true research is severely limited. This calls for constantly more and more specialized knowledge, and the laboratory which the writer is about to describe was organized to study and develop new and economical methods for the separation of particles in suspension and for their more intimate admixture. The special requirements necessary for work in this field were happily already possessed by the Dorr Company's scientific staff, inasmuch as the field in question indicates the general scope of the Dorr apparatus. But the successful operation of the laboratory staff in the solution of problems within the domain mentioned has led to the undertaking of work quite outside of these limitations, so that its scope has been greatly extended beyond the original plans for the establishment.

A research laboratory differs from everything else under the sun. Generally speaking, the more we know of a thing the better can we tell what it will do or accomplish. With a research laboratory, however, the more scholarship and scientific understanding we bring to it the less can we tell what will come out of it.

The metallurgical and chemical apparatus invented by J. V. N. Dorr have been fully described in previous issues of CHEMICAL & METALLURGICAL ENGINEERING.[1]

They were thoroughly established in the cyaniding industry, but the inventor set himself the problem of introducing them generally into industry wherever a use for them might be found. Outside of cyaniding they were practically unknown until Mr. Dorr moved East from Denver, leaving a metallurgical branch and testing laboratory behind him when he established headquarters of the company that bears his name in New York, and surrounded himself with a competent scientific and technological staff.

NECESSITY OF RESEARCH APPARENT

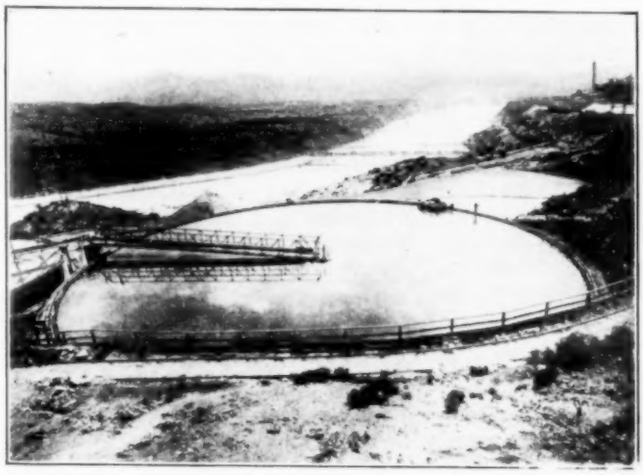
At this point the necessity of research became evident to fill in the gap between Why and How. It was easy enough to ask, for instance, why wouldn't a thickener

[1] "The Use of Hydrometallurgical Apparatus in Chemical Engineering," by John V. N. Dorr, January and February, 1915, pp. 55-59 and 91-98.

clarify the waters coming from an anthracite coal washer, save the coal and avoid the pollution of streams? But you can't sell apparatus or anything else on a question. Men of affairs are singularly averse to buying problems. On the other hand, if you can tell them how to solve their problems they become interested immediately. Here is the direct incidence of research. And very fortunately the substance of the little homily at the beginning of this article in regard to the subject was clear in the mind of the inventor. He wanted a place where work might be done in peace and quiet, apart from noise and distractions, and where the men at work would be free from the misery of a high-rent time clock to worry them to undue speed or omissions. It is remarkable how closely allied is academic calm to industrial research. The very thing to avoid is the slap-dash bustle and the emphasis of so-called "scientific" management in such a laboratory. If a man can think better when he dawdles with his figures there is no reason why he shouldn't dawdle with his figures. If the man in authority lacks scientific understanding his only safety is to leave the place alone. It is much better for such a person to say his prayers over the laboratory than to give instructions in it.

Old Mill Becomes a Laboratory

Mr. Dorr purchased for the use of his organization an old mill at Westport, Conn., built way back in the seventeen hundreds, with good water power and about thirty-five acres of mostly wooded land. The mill was



200-FT. DORR THICKENER

reconstructed for laboratory purposes and for semi-commercial and commercial testing. It was provided with a considerable variety of small, medium and some full-sized apparatus for grinding, separating, drying, etc., besides a good metallurgical outfit, and an extensive chemical and a fair physical laboratory equipment.

An excellent library is provided with a big fireplace and comfortable chairs and tables, there are comfortable sleeping-rooms, and—the writer is speaking from experience—a grand breakfast may be prepared there. There are trout in the stream which runs under the mill, the woods about it are a bird refuge, and near by a couple of houses are approaching completion for the greater convenience of those engaged there. The place is forty-four miles from New York and about four miles from South Norwalk, which is an express passenger station on the New York, New Haven and Hartford R.R. The laboratory has a permanent staff of four research engineers, together with attendants and laborers, and usually there are four or five more chemists or engineers trying out new ideas, or working on improvements in methods of separation or mixing, or in research along other lines. These extra men may be members of the company's own staff or from those of its clients.

Some of the Problems Studied

The scope of the work undertaken at the laboratory may best be set forth by a list of the subjects of some of the problems already studied, and it also indicates how far beyond the original field of wet metallurgy the use of these apparatus has been brought by the application of intelligent research. The list includes: Leaching copper and tin ores, flotation of copper, tin, iron and lead ores; studies in connection with the production of Chilean nitrates, clays, bauxite, alum, feldspar, iron ores, phosphoric acid, acetylene, abrasives, coal, cement, dye wastes, fluedust, kaolin, lithopone, limestone, magnesia, oils, paper pulps, paints and pigments, rubber, starch, sewage, soap, etc. A curious example of research in this laboratory was one which resulted in an advance in the technology of making false teeth.

Operations of the Laboratory

The operations of the laboratory may be divided under the following main headings:

Research dealing with the development of the company's ideas in connection with processes and equipment;

Research for clients often along lines which do not involve the use of the company's apparatus; and

Testing for the enlightenment and instruction of the sales forces.

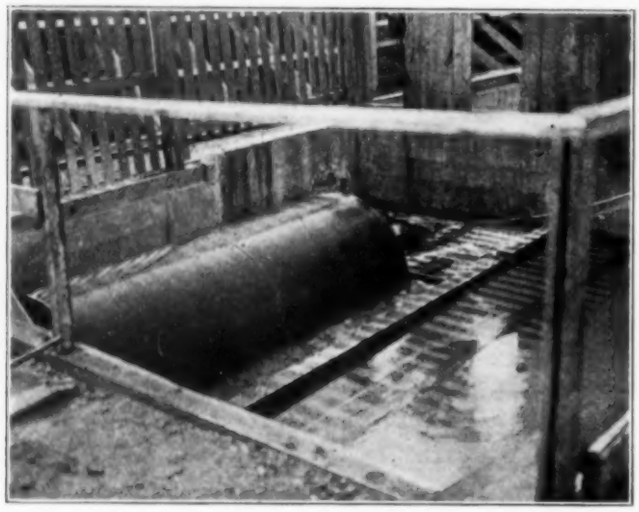
Experience has demonstrated that what may appear to be a simple testing problem generally calls for careful research before a definite report can be rendered, and in view of this the company has adopted the policy of charging for all but those forms of simple testing in relation to sales which do not in any way call for analysis or research. Here we have an excellent example of laboratory growth: starting as a testing out plant to aid sales, as its competence develops it becomes a commercial laboratory. And the policy of charging for the study of manufacturers' problems enables the corporation to avoid tacking the cost of special research on the price of apparatus. It also makes it possible to maintain standard prices for apparatus.

Wholly apart from the services mentioned the laboratory plays a further important rôle as a mistake eliminator.

Some of the Things Accomplished

Some of the things accomplished that began in the laboratory as ideas which were tested out on a theoretical scale and later developed in part in the apparatus installed and in part in field work are the following: The art of "closed-circuit grinding," for instance, was well known in wet metallurgical work, but new to chemical technology outside of that domain. It needed the laboratory to demonstrate its usefulness in such industries as the production of pigments, floated silica, milk of lime, etc. Here, too, the idea was first considered to use thickeners to recover the dust from blast-furnace gases in which up to 47 per cent of iron is entrained. The method of introducing Dorr apparatus into clay

industries was worked out here, as also the saving of large quantities of coal from anthracite washeries, already referred to, and, at the same time, avoiding the pollution of streams. One of the sequelæ of this work was the establishment of a branch office in Scranton, Pa. A later development is in the bituminous washeries, also saving coal and avoiding the pollution of streams. It required preliminary testing to prove the use of apparatus in cement mills and in the separation of fine phosphate rock from clay. A major problem had to do



REVOLVING SCREEN FOR TRADE WASTE

with the handling of hot saccharate in the Steffens house of beet sugar establishments and for concentrating this precipitate under conditions of heat control prior to filtering, and for thickening the first carbonization precipitate. An allied problem worked out and successfully put into practice in the operation of a cane-sugar mill was the production, without filtration for subsequent evaporation, of a bright juice which is practically free from suspended solids. An unlooked-for secondary result which developed in field tests was that the underflow was much denser (liquid : solid ratio) than is otherwise obtained. This promises to eliminate a second decantation, which is a fertile source of loss.

Improved Treatment of Sewage

Another field in which research in the improved separation of solids from liquids was indicated and begun was in the treatment of sewage. The work started several years ago with problems relating to trade wastes which led to the development of a self-cleansing rotary screen, and this in turn warranted an attack upon the great question of the disposal of domestic sewage. Success in handling trade wastes led to the organization of a special sanitary department of the Dorr Company.

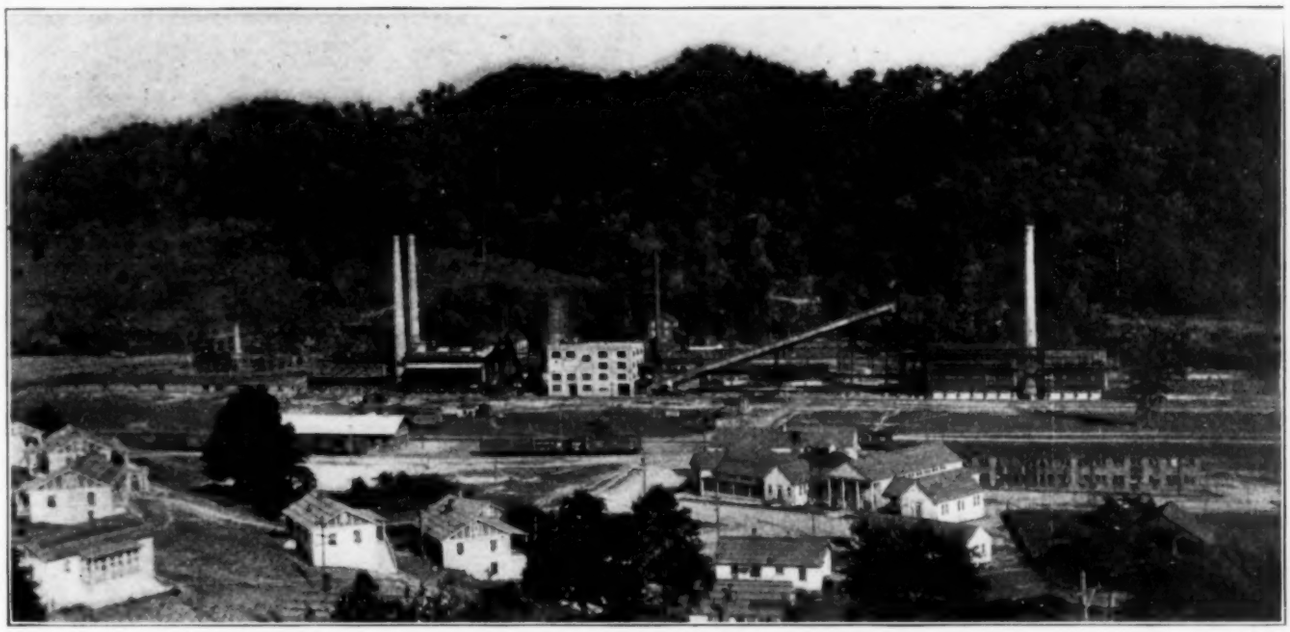
The domestic sewage problem is so pressing that it will probably be of interest to indicate the incidence of the work, although a complete solution of the problem is not yet at hand. When stream pollution is to be avoided, an affluent of high purity is required, which will be allowed to flow away without nuisance resulting. A desirable method of producing this purification is to activate the sewage—that is, to bubble air through it until oxidizing bacterial cultures are formed which destroy and absorb the offensive matter in the sewage. A clarified stable water effluent is produced, the impurities being separated in solid form by settling as "activated sludge."

The great difficulty with all sewage activation processes is that they require so much air that the factors of cost and time become a heavy burden. The new revolving screen operates in conjunction with this process by removing the sizable tough and non-digestible solids from the raw sewage prior to activation, thereby lessening the purification work of the bacteria. The activation takes place in a specially designed clarifier (or thickener) which effects distribution of circulation of the air bubbles in one chamber and separation of sludge from clear effluent in another. The indications are that aëration may thus be accomplished in less time and at lower expense than by other means. The aërated sludge then passes to final treatment.

Undeveloped as yet, but making progress under the auspices of this company as well as in other research laboratories, is the biological treatment of the sewage so that it shall have enough nitrogen when dried to be a high-grade rather than a low-grade nitrogen fertilizer. Dried activated sludge is not a nuisance. The other features, the removal of grease by mechanical means, the immediate treatment of sewage as it flows from the sewer and before it has become septic, with the avoidance of great settling tanks; the enclosed, unsmelled and unseen mechanical treatment from start to finish; the chlorinated clear and harmless effluent that flows away and the dried sludge fertilizer brought out as the final product of one operation, all push along toward the solution of these perplexities. The research of this company's group of chemists and engineers, in conjunction with the work done by others during the past twenty-five years, leads to hope that the Desired Thing is not far off: the inoffensive disposal of municipal sewage, an end to the pollution of surrounding waters and neighboring streams, the resolution of a present danger to health into an inoffensive sanitary disposal plant; a boon to agriculture and a source of profit rather than an expense to municipalities.

Research and Industrial Wastes

In a paper read by George S. Hessenbruch at the Indianapolis meeting of the American Society of Mechanical Engineers the following points were emphasized: In many instances the financial returns from the wastes when properly processed and obtained from the raw materials in a manufacturing plant have been greater than the return from the actual manufactured article made in the same plant. Today we are confronted by the cry of increased production. Every manufacturer is striving his utmost to help this movement. In fact it is the solution or at least an amelioration of many of the evils that threaten us seriously, and it is natural to turn toward the utilization of wastes and waste materials, which is the most economical and beneficial way to help this movement. Reducing the wastes or utilizing them in some way or other by suitable processing will not only save the national resources from being depleted more rapidly, but it will also reduce costs, establish new industrial undertakings, give employment to more people, open up new channels of commerce and induce capital to invest in new enterprises. The meaning of all this is fully realized and industrial as well as pure scientific research is gradually receiving more and more attention.



GENERAL VIEW OF CLINCHFIELD PLANT

Low-Temperature Carbonization of Coal and Manufacture of Smokeless Fuel Briquets

Low-Temperature Carbonization of Coal Compared With High-Temperature Carbonization—The "Carbocoal Process," Retorts, Machinery, Etc., Installed at the Clinchfield Plant

BY HARRY A. CURTIS, PH.D.*

THE conversion of bituminous coal into a smokeless fuel by any commercially feasible process is a project of first-rate importance, not alone because of the interesting engineering and chemical problems involved but also on account of its vital economic bearing.

LOW-TEMPERATURE CARBONIZATION COMPARED WITH COKE-OVEN PRACTICE

When a given coal is distilled or carbonized, there are several factors which influence the quantity and the composition of the various byproducts, but of these factors temperature is the dominant one. In the ordinary byproduct coke oven, where the prime object is to turn out a special product for the metallurgical industry, the carbonization is carried out at a temperature far above that which is favorable to a high yield of oils. The resultant coke is too inert and too high priced a product to find favor in the domestic fuel market or in the industries generally.

If coal be carbonized at lower temperatures, say at about 900 deg. F., the yield of oils per ton of coal will be more than doubled, while the gas yield is correspondingly much less. If a coal of the following proximate analysis be used

	Per Cent
Volatile matter	35
Fixed carbon	58
Ash	7

the yield of the various products will be as follows (assuming that a coke oven could handle so high volatile a coal):

	High Temp.	Low Temp.
Coke residue, per cent	66 (1% volatile)	72 (10% volatile)
Gas, cu.ft.	10,000	4,000
Tar, gal.	12	24
Light oil from gas, gal.	3	1½
Ammonium sulphate, lb.	20	10

The coke residue in the two cases will be quite different in character, the higher-temperature product being harder, coarser grained and more inert in the fire, while the low-temperature residue is light, relatively soft, friable and easily burned.

The high-temperature carbonization in the coke oven yields much more gas than does low-temperature carbonization, but the coke-oven gas will be lower in average heat value, say 550 B.t.u. as compared with 750 B.t.u. for the low-temperature process. This difference is, of course, due to difference in composition, the low-temperature gas corresponding more nearly to that which is produced in the coke oven during the earlier stages of coking.

The tars produced are quite different in composition. An indication of this is that while the specific gravity of good coke-oven tar will run about 1.17 at 60 deg. F. and the tar will show a free carbon content of about 6.5 per cent, the low-temperature tar will run less than 1.1 specific gravity and have a free carbon content of less than 1 per cent. In general, the low-temperature tar contains more paraffine bodies and less aromatic

*Chief Chemist, International Coal Products Corporation.

compounds than does coke-oven tar, but the tar acid content of the low-temperature tar is higher. For example, on distilling the tars, the 170 deg. to pitch fraction of the low-temperature tar will contain about 40 per cent tar acids, while the distillates from coke-oven tar will run less than 15 per cent tar acids. The low-temperature tar distillate contains only a trace of the phenol which is characteristic of coke-oven tar, but the "phenol coefficient" of the low-temperature tar distillate will run higher, due to the fact that the cresols are more powerful disinfectants than is phenol. Naphthalene is evidently a high-temperature product, for it is absent in the low-temperature tar.

The light oil recovered from the gas in low-temperature carbonization differs from that obtained in coke-oven operation in that the former contains about 20 per cent of paraffines mixed with the usual benzene, toluene, etc. In war times, when pure benzene and toluene are needed, this is a disadvantage, since the paraffines must be removed, but in peace times, when this oil will normally be worked up into motor spirits, the presence of the paraffines is an advantage because it lowers the freezing point of the mixture, whereas the corresponding product from the coke oven must be mixed with gasoline for winter use.

The ammonia produced in low-temperature carbonization is only about half that yielded by the coke oven. It is known that when coal is distilled, evolution of ammonia begins at about 650 deg. F. and practically ceases at about 1,450 deg. F. The distillation at an intermediate temperature, 900 deg. F., without steaming, necessarily gives a low yield of ammonia.

The "Carbocoal Process"

The Carbocoal process for producing an anthracite-like fuel from bituminous coal is not purely a low-temperature process, since the soft semi-coke obtained in the initial low-temperature carbonization is subsequently briquetted with pitch and then carbonized at a relatively high temperature. This point should be borne in mind in comparing the yields of the Carbocoal process with simple low-temperature processes. Also it is not correct to compare the yields of the Carbocoal process directly with the yields of the byproduct coke oven, for while the tar from a coke oven is marketed as such, in a Carbocoal plant the tar is distilled and the pitch returned to the process, tar oils being marketed in place of tar.

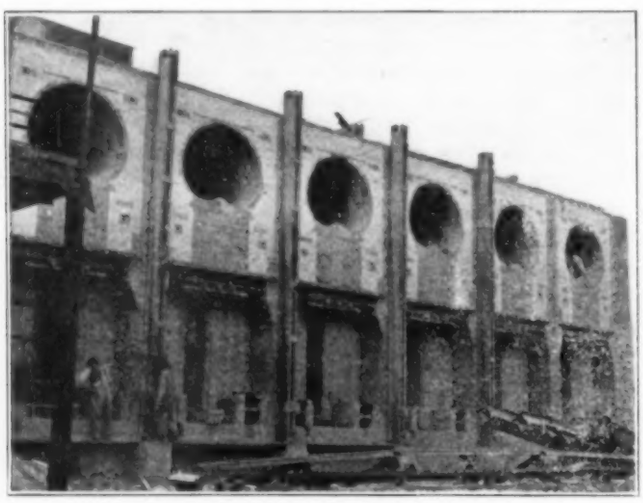


FIG. 1. BATTERY OF SIX LOW-TEMPERATURE RETORTS IN COURSE OF CONSTRUCTION

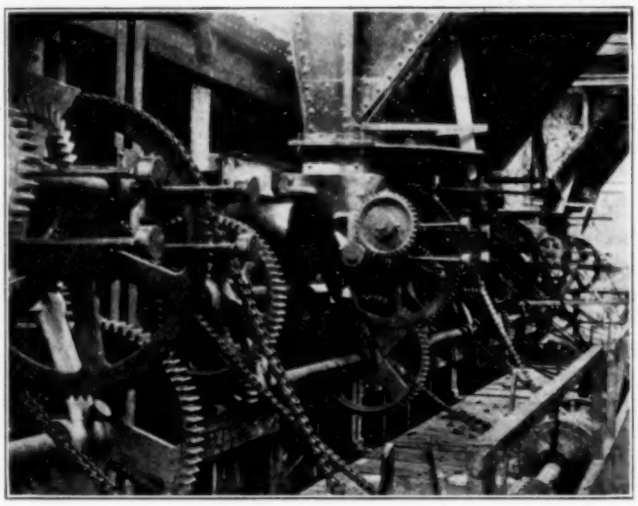


FIG. 2. FEED AND DRIVE MECHANISM

In the Carbocoal process the coal is first crushed to pass a ⅜-in. screen and is then fed by screw conveyors into horizontal retorts. Each retort is about 7 ft. in diameter and 20 ft. long, lined with carborundum and carrying two heavy paddle shafts running lengthwise through it. Each shaft carries about forty paddles, so arranged that when the shafts revolve the paddles stir the coal continuously and advance it slowly through the retort. The advantage of moving the coal up to the hot walls of the retort instead of depending on the transfer of heat through the coking mass is obvious.

The yields obtained in this step of the process are those represented under low-temperature carbonization discussed above—i.e., about 4,000 cu.ft. of rich gas, 24 gal. of tar, 1½ gal. of light oil and 10 lb. of ammonium sulphate.

The semi-coke which is continuously discharged from the retorts may be used directly under the boiler of a power plant or may be charged directly into a gas producer. It is, however, not in shape to market for general use, being too soft and carrying too many fines. In the next step in the process this soft semi-coke is ground and briquetted with hot pitch, heavy roll presses being used for this work. These raw briquets are like the usual smoky coal briquets which have done much to prejudice the market against briquetted fuel. In the next step in the process, the raw briquets are charged into inclined rectangular retorts and carbonized for about six hours at 1,800 deg. F. During this time the briquets shrink about 30 per cent in volume, the pitch binder is coked, and the hard, dense briquets resulting finally are quite smokeless when burned.

The high-temperature carbonization results in a further yield of byproducts—viz., about 6 gal. of tar per ton of coal, about 5,000 cu.ft. of gas, an additional 10 lb. of ammonium sulphate and a little more light oil.

In a Carbocoal plant, the byproducts from the primary or low-temperature carbonization are combined with the corresponding byproducts from the secondary or high-temperature carbonization, and worked up as usual.

In order to compare the output of a Carbocoal plant with that of a byproduct coke oven, it may be assumed that the tar is distilled in both cases, the pitch in the case of the Carbocoal process being turned back. In the accompanying table the pitch from coke-oven tar

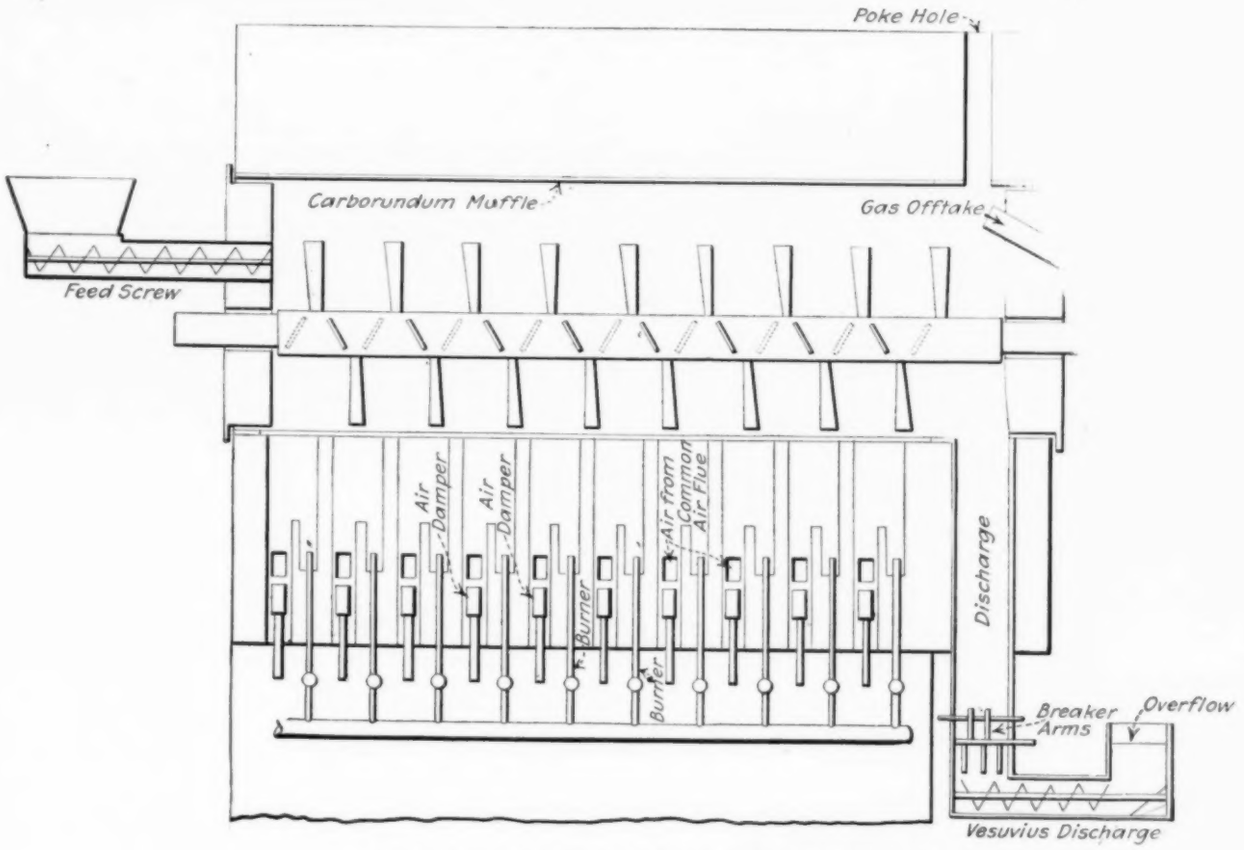


FIG. 3. CROSS-SECTION OF PRIMARY FURNACE

is taken at 68 per cent the volume of the tar and the pitch from the Carbocoal process at 50 per cent the volume of the tar. The yield of Carbocoal will be a few per cent higher than the coke for two reasons—one that the Carbocoal still carries 3 to 4 per cent volatile, and the other that the pitch used in briquetting yields some coke in the secondary carbonization.

YIELDS FROM A TON OF DRY COAL
(See analysis in text)

	Coke Oven	Carbocoal Process
Coke or Carbocoal, per cent	66	68
Gas, cu.ft.	10,000	9,000
Light oil from gas, gal.	3	2
Ammonium sulphate, lb.	20	20
Tar oils, gal.	3.8	15
Pitch, gal.	8.2	Used

The coal is assumed to have the analysis given earlier in this paper, which makes the coke-oven yields appear a little unusual, since a coke oven seldom uses so high volatile a coal.

The Clinchfield Carbocoal Plant

The Carbocoal process[1] was developed during the past five years by the International Coal Products Corporation at its experimental plant in Irvington, N. J. Most of the work here was done with commercial-sized retorts, since it was clear from the nature of the problem that small-scale apparatus would not yield the necessary mechanical data on which to design a commercial plant. The experimental plant at Irvington has a capacity of about 100 tons of coal per day, but this plant is operated strictly for experimental and development purposes.

[1]See CHEM. & MET. ENG., vol. 19, p. 579.

During the war the United States Government financed the construction of a 500-ton-per-day plant at Clinchfield, Va. This plant was finally put into operation in June, 1920, and has been running steadily since. Full-capacity production will be reached during the present summer.

The Clinchfield plant is equipped with twenty-four primary, or low-temperature retorts, each having a capacity of 24 tons of coal per day. The coal used is a good grade of bituminous coal coming from mines a few miles from the plant. After crushing, the coal is delivered to feed hoppers over the retorts from which it is carried into the retorts by self-sealing screw conveyors. The semi-coke is discharged continuously by similar self-sealing screws and falls onto closed conveyors which deliver it to storage bins in the briquet plant. Here it is ground, fluxed with pitch, and briquetted on heavy roll presses. The raw briquets fall onto a long, cooling conveyor and are delivered to storage bins at the secondary or high-temperature retort, whence they are charged into the retorts from steel larry cars.

There are ten secondary retorts arranged in batteries of six and four, each retort about 12 ft. wide and 20 ft. long, inclined at about 30 degrees and divided into six carbonizing chambers. After the final carbonization of about six hours at 1,800 deg. F., the finished briquets—Carbocoal—are discharged by gravity, quenched and loaded for shipment.

The byproducts are handled as in coke-oven practice, the Clinchfield plant including a complete byproduct plant, tar-distilling plant, light oil plant, power plant and all auxiliary equipment necessary to make it a self-contained unit.

The Chemical Profession—Its Opportunity and Responsibility

An Outline of the Growing Effective Effort of the Chemical Profession and of the Necessity and Duty of Chemists to Enlist Capital, Brains and Natural Resources for Concerted Action in the Development of the Chemical Industry

By R. S. McBRIDE*

THE chemical profession today stands at an open door of opportunity. Indeed, every indication of the times is an invitation to enter upon a new era of growth and achievement that is most alluring. With the opportunity comes also a duty. The duty is one requiring not only service but also expansion and growth of the profession in many lines. Never before has the chemical profession seen such an ideal blending of a promising future for itself with a splendid chance to render a large service to the world. The profession is young, but it deals with basic and essential activities. It goes into all branches of industry with far-reaching influence. No one can today prophesy the immediate opportunity, much less foresee the increasing power, of effective chemical effort properly developed in future years.

All of this would seem to be a statement of generalities of little interest or practical value if there were not at hand readily available means for the realization of these dreams. A simple analysis of professional activity makes many of these points clear.

The Basic Chemical Reaction

Chemistry is principally applied for the control of industrial processes. In this application we can write one simple basic "reaction" which covers practically all of its activity.

Resource + process + labor and power + management and scientific skill + money = product + byproduct + profit.

This industrial reaction goes on successfully under a wide variety of conditions. American business methods and the atmosphere of American science seem particularly conducive to high yields of all of the products of the reaction. Particularly does skill in science and management furnish a splendid catalyst for the reaction.

The Yardstick of Chemical Success

Measuring the speed of this reaction we cannot use the unit of product or unit of time, but we have two most effective yardsticks. The financial measure of success, of course, is expressed in terms of the dollar; and to the extent which the third product of the above reaction predominates, our financial and business interests would say that we had achieved success. On the other hand, we have the measure of scientific success. There is first the extent to which we have conserved our resources. There is also that measure of success which depends upon the improvement in quality of product or lessening the cost of a product of given quality. And the still more rigid test of achievement is that we shall have furnished something novel which is useful either as a substitute in old work or for the accomplishment of new results.

Profession or Trade

Chemistry is unquestionably practiced in this country as a profession. It has, however, many hangers-on who lend to it the characteristics of a trade. As a profession it believes fundamentally in the application of knowledge. In this it is distinguished from a trade, which inevitably rests largely upon the application of experience rather than application of knowledge. This distinction between profession and trade is fundamental. Without clear recognition of it the advancement of chemistry will be much handicapped and delayed. Fortunately, however, chemistry has through very recent years been granted a new vision which gives promise that it will recognize this distinction.

As a science, of course, chemistry dates back into early times, but modern chemistry has successfully avoided the pitfall of ancestor worship. It has taken all of the Anglo-Saxon characteristics of independence of thought and vigorous advancement of new ideals. There remains, however, additional responsibility. Particularly with respect to organized professional effort it has not correspondingly advanced.

Organized Chemical Duty

Turning back to the basic reaction of industrial activity, we should ask ourselves, What has organized chemistry done or what is it doing today in the direction and control of industrial reaction? To what extent has it gone into the market for capital, for brains, for natural resources? How has it encouraged the development of the process and machinery, patents and inventions? Wherein has it influenced the market conditions for its products and byproducts tending always to produce well-balanced industry?

In almost every case we are forced to reply that *collectively* chemists have done almost nothing. What might or should have been done is all too obvious to the careful student of the situation. In impetuous, youthful attack upon its everyday problems, however, the profession has ignored these duties and today seems to stand in need of reprimand. However, it is by no means too late to induce those efforts which will be effective in this work, for they are only latent in the chemical profession.

The Bid for Capital

Chemical industry today is not recognized as such—that is to say, that potent element of industrial development, the financier, does not recognize chemical activity collectively as such. This is in striking con-

*Engineering Representative, McGraw-Hill Co., Inc., Washington, D. C.

trast with the railroads, the public utilities, the mining and metallurgical interests of the country. All of these and others go into Wall Street as a group and demand there and receive financial attention and backing. To date, however, the chemical profession has not developed a similar respect and attention for the chemical demand of the country.

Recently the electrical appliance interests of the country were urged to attend to matters such as this. Editorial comment to them emphasized: "Your banker is your best business friend. Get acquainted with him and see that your bank officials become acquainted with your business and with the facts about the great electrical industry of which your business is a part." The comment continued to set forth the more essential and less essential lines of electrical merchandise and supply that demand financial support during the coming year. The amazing total of estimated sales aggregated about two billion dollars in merchandise for 1920. Surely the chemical industries could make an even more impressive showing, but they have never even attempted such a demonstration.

The electrical business taken at large is regulated. Profits are severely limited in many lines by the price-fixing activities of our public authorities, and yet this business successfully commands the interest of the banker and his support. How much more readily the chemical industry, young, rapidly growing and prosperous as it is, can command this attention may well be appreciated. But not only is this opportunity greater, the financial demand is greater too, for it is the growing industry which needs the greatest amount of new capital. In greater proportion, too, is our responsibility for this important aspect of professional effort.

The Search for Resources

The chemist should not be content to let the geologist, petrographer and mineralogist alone seek the resources of the country. He, too, must go into the field, not in person, perhaps, but by proxy, always seeking the natural industrial resource which is to be basic for his processes. Economic geology today is really resource chemistry. The industry of tomorrow must depend upon explored resource of today. Imports, exports, tariff and many other related questions are only beginning to receive their deserved attention by chemists. Individually we have begun to appreciate their importance. Collectively they are as foreign to the profession, it appears, as Greek or archæology.

Processes and Machinery

For successful development new processes and new machinery must continually be furnished. Only by individual effort and private support can invention be first conceived, but much of this invention which promises well for the industry will fail unless it receives more than this individual support. Full records of progress must be made in order to facilitate wider expansion, wider application of new developments must be always encouraged, and co-operative effort in support of new and worthy undertakings must never fail, if the chemical profession is most quickly to realize upon the new ideas.

Chemists must work together in these lines. They must co-operate to speed up the progress from research to achievement. This process is not simple, as we all know. Research leads to discovery. Discovery leads to invention. Invention leads to development. Development leads to industrial accomplishment, and accomplishment leads to industry. It is a stairway of achievement having many steps. Individually many of the steps are far too high to be negotiated. Collectively the profession need fear none of them.

Today in the chemical industries we find many striking examples of widespread application of simple equipment or process, as, for example, the filter press. Many industries have borrowed this device and put it to good use. Colloid chemistry, first studied by the "pure" scientist, who thought only of its theoretical meaning and possibilities, today is being recognized as a dominating influence in many industrial fields. Innumerable other examples might be cited. However, set against these we have whole industries neglected by the chemist. Fertilizers are prepared almost without the thought of chemistry. Coking except in a very few cases is undirected by science; it remains a mechanical-engineering art, almost in fact a trade, so largely is it guided by rule-of-thumb methods. It is almost inconceivable that the chemical profession will permit these and many others to remain without the dominating influence of proper professional attention.

Labor and Power Problems

Today the chemist for greatest industrial success must be something of an engineer economist. He must study labor, immigration, emigration, finance, and related problems diligently.

Much of the chemical progress will result in reducing the demand for labor in industrial processes; but simultaneously we create corresponding increase in demand for mechanical power. We thus add a need for study in the field of water power, electric power transmission, fuel prices, and related industrial requirements.

Today all industry is in competition for the supply of labor and for the supplies of fuel and power. The chemical industry cannot ignore this competition. To be sure, a young and thriving industry can usually afford to pay almost any price for essential materials or services, because the margin of profit is great; but the measure of *permanent* success will be determined by the extent to which efficient use is made of labor and by how fully the well-co-ordinated intelligent bid for power and fuel is made while directly meeting other industrial competition for these items.

The chemists working together must study these questions. They are not simple nor will they be solved in a year, nor even a decade. They will continue so long as industry continues, but ignoring them will at no time be safe.

The Needed Brains

Individually the chemist has done much in each of the fields which has been mentioned. Collectively he has done little. Least of all has he been attentive to the problems of training up for the future of the profession the needed younger men.

Chemistry offers a romantic field for study to the youngster who may desire to consider science as a life work. More effort should be made to encourage this selection. Recently there has been some such movement, but all too little has been done along these lines. As the chemist of today goes forward in his profession, advancing from year to year in responsibility of position and size of organization directed, he will feel in-

creasingly the need for younger men to assume direction of the details of his work. Unless there is soon a strong effort made to advance the professional standards in teaching and to strengthen the college curriculum, a most distressing lack of talent will confront the executive in the not distant future. It will not be enough to have many students studying chemistry. In fact, it is doubtful whether great numbers of students in this field will be any advantage at all. Much greater effort must be made to develop the quality of work done and the standards of performance required in the chemical curriculum so that the men coming out will be the very cream of our student body. In order too that the best and most vigorous minds among the younger men will choose to go along these lines, the rosy future in opportunity for service and achievement must be clearly painted before their eyes.

Persistent advertising of a profession makes for its future success. It is perfectly proper that there should be developed a dignified sense of professional self-importance. There is nothing to criticise and everything to commend in such a policy. Of course we will find amusing results from this and some criticism will doubtless follow from time to time. Particularly striking exaggeration of this sort was spread broadcast by the much-advertised U. S. Marines quite recently. In emphasizing the opportunities of this "wonderful" service, they blazoned forth on billboards the natural steps in achievement for a young man as follows: The steam fitter becomes the steam engineer, the steam engineer the mechanical engineer, and the mechanical engineer finally achieves still higher plane as electrical engineer, who in turn may attain the highest pinnacle by a certificate of proficiency in the U. S. Marines.

We certainly do not agree that electrical engineering should be placed above mechanical engineering—rather they are on a par. Still less would we agree that a certificate of marine proficiency is the pinnacle of all achievements, but the electrical engineer working vigorously through all proper professional channels has put across the idea that electricity is the most modern of activities, and we have through this poster a reflection of the success in advancing this idea.

We wonder what will be achieved when the chemist starts a similar campaign. Certainly we may anticipate that the popular conception of today regarding the chemist will be much improved, for today the chemist varies in the popular mind from a wizard to a glorified bottle washer. Either extreme view is popular. The correct impression of his purpose and function in our modern economic life is rare indeed; and he has only himself to blame.

The Major Remedy

There is today in the chemical profession ample vision, ample knowledge, ample energy, but all potential and undirected. The need is not greater enthusiasm; rather we require co-operation, co-ordination and concerted action. In every case the element of working together must stand foremost.

Approximately 20,000 men in this country today can properly be styled "chemist." Every year the numbers are increasing by thousands. The potential force of this group is tremendous if the group will work together. They can command attention in any field. The professional spirit, quite the equal of that to be found in our major engineering activities, will be assured; and we shall have one tremendous asset which up to the present time the engineer has always lacked—that is, a single professional group.

The American Chemical Society stands today perhaps as great a scientific achievement as has been recorded by any group in any natural science. It has, however, been compelled to neglect practically all of the professional responsibilities to which the engineering bodies in the electrical, mechanical, civil and metallurgical field have given attention. It is these activities and these functions for which the need today is greatest. Individual effort or effort of small groups in individual industries will not suffice. We should not discard the tremendous asset of working altogether in a single big body, including all chemists, organic, inorganic, theoretical, industrial or otherwise. However, this group must more keenly appreciate and more vigorously prosecute these professional lines of effort.

Chemists and Chemical Engineers

On the occasion of the official inspection of the new laboratories at University College, London, Lord Moulton delivered an address on "The Training and Functions of the Chemical Engineer." In this address, as reported in London *Chemical Age*, vol. 2, p. 300, Lord Moulton said that the chemist as opposed to the chemical engineer reminded him of the difference between the mathematician and the mechanical engineer. The mathematician figured out his calculations, and his plans did not wear out. The mechanical engineer, on the other hand, worked with materials that did wear out. When the chemist became a chemical engineer he stepped from the ideal into the material world. His methods were practical, and he found himself forced to follow in the steps of the great chemists without their advantages yet bound to obtain their success. The chemical engineer worked for production on a scale that the needs of mankind demanded and he therefore abandoned the scale of the laboratory. Change of scale was more important than people imagined. It seemed very little different to work with bigger plant, and to deal with more substance than to deal with the same substance on a smaller scale. But just because it seemed not to make so great a difference change of scale was more likely to lead clever men into trouble than almost any change of conditions one could think of. Change of scale was a very difficult thing to allow for, but it was the secret of successful chemical engineering. As an illustration of the expense which change of scale involved, and the reason he put it down as the great characteristic of chemical engineering as contrasted with research chemistry, Lord Moulton said he once knew the head of a great engineering business in the North of England who prided himself on having cooked an ox whole so that it was well cooked in every part. Many people could cook a joint, but he doubted whether any of the professors of the college would undertake to cook an ox whole, and have every part well cooked. There they had the chemical engineer. This change of scale brought into the task of the chemical engineer some very difficult problems, for he had to see that everywhere the right conditions ruled. Whenever Lord Moulton had seen chemical engineering on the scale at which it had to be done to satisfy our wants, it had impressed him that things one never dreamed of as being important became serious considerations when dealing with large masses.